Copyright

by

Dawn Marie Wittke-Bender

May 2014

The Thesis Committee for Dawn Marie Wittke-Bender
Certifies that this is the approved version of the following thesis:

Advancing Lighting for Aquaria

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor:

Michelle Habeck

Susan E. Mickey

Advancing Lighting for Aquaria

by

Dawn Marie Wittke-Bender, B.A

Thesis

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Fine Arts

The University of Texas at Austin

May 2014

Dedication

Dedicated to my grandparents, Rayetta and Fred Wittke. Also to Shawn Bender for his love, patience and support; without which this would not have been possible.

Acknowledgements

First I would like to thank Shawn Bender, my collaborator and confidant. Also, I would like to thank the entire *Seatrical Lighting* team. Without these individual's hard work, this project would not have been possible: Rachel Bennick, Malori Carr, Lauren Gallup, Jared LeClaire, Julie Maury, Terrance Mitchel, and Maegan Wilson. Additionally, I wish to thank many other individuals who contributed time, money, advice, information, or other support to the project: Dr Daniel I. Bolnick, Timothy Miller, Andrew Carson, Jerry Acuff, Larry Resch, Bryan Bender, Rebecca Wittke, Fred Wittke, Carol and Raymond Bender, Drea Olivaries, Justin McNulty, Ben Fest, Herb Woerndell, Jeff Ellinger, and Austin Shirley.

This project was made possible by the kind and generous donations of Aquatic Design and Aquariums LLC, The Texas Cichlid Association, and DFW Aquarium supplies Inc. Additionally, I wish to thank The University of Texas Department of Theatre and Dance, and the Design Faculty.

Finally, I wish to express my deepest gratitude and appreciation to my advisors Michelle Habeck and Susan Mickey for their invaluable support and guidance.

Abstract

Advancing Lighting for Aquaria

Dawn Marie Wittke-Bender, M.F.A

The University of Texas at Austin, May 2014

Supervisor: Michelle Habeck

In this thesis I will explore the creation of a professionally advanced aquatic lighting fixture that will offer more flexibility than is currently available in the professional aquatic lighting field. I will investigate how the flexible fixture can enhance aquatic microenvironments through application of a design approach. In this investigation I will focus on the visual composition of light within the aquarium, while providing physiologically supportive light to the living inhabitants of the microenvironment.

In order to explore this process I will create a LED aquatic lighting unit that shares many of the properties of a traditional theatrical lighting grid; specifically: flexible positioning, focusability of light sources, color control, and intensity control. I will design and build this flexible unit, and demonstrate its capabilities on a minimum of three contrasting aquatic microenvironments. The project will be displayed in an exhibit within the Winship Theatre building, where the human viewing environment will be designed to provide a soothing light and sound enhanced experience.

Table of Contents

List of Illustrations

BACKGROUND

Practicing as a theatrical lighting designer, coupled with my past experience of working in the aquatic industry, I realized the existence of a specific potential to change how lighting in the professional aquatics industry is approached. In theatre, we depend upon the flexibility of lighting to be able to sculpt a scene with an expressive approach. We choose varied instrumentation, we specify where each instrument is placed, and carefully determine at which angle the lights approach the subject of focus. In aquarium keeping, however, there is a rigidity that does not allow such choices to be made due to limited lighting resources currently available on the market. In my observation, it is obvious that there is an apparent gap in approach between aquatic lighting and theatrical lighting. I will argue that a combined approach will strengthen the design quality of aquatic lighting by adding an increased level of flexibility and focus to standard aquatic lighting fixtures.

I will create a fully customizable, flexible lighting unit that will allow lighting design of microenvironments that embody theatrical qualities of an expressively designed and sculpted living composition.

SCOPE OF PROJECT

WHAT LIGHT MEANS TO LIFE

In setting out to create an aquatic lighting unit, it is important to note that there is a physiological aspect to lighting aquaria. The aquatic microenvironment's inhabitants--whether fish, amphibian, coral or plant-- have specific needs that must be met to ensure survival. Some, including myself, argue that for any animal there is also a psychological aspect to consider in addition to the physiological aspect. The animal is confined to an artificial environment of our creation and control; it is up to our ethics to provide the best husbandry and most beneficial environment possible.

At the most basic level, to fulfill both this physiological and psychological need, the lighting in the aquaria must provide a "photoperiod," or set times of darkness and light. It also needs to provide both UVA and UVB spectrums of light. Beyond those criteria, needs vary by species, for instance: nocturnal creatures are active at night, diurnal creatures are active during the day, and crepuscular creatures are active at twilight. Even species-specific behavior such as top-level swimmers vs. mid-level swimmers vs. bottom dwellers has a direct correlation with lighting needs.

MY CONTRIBUTION TO AQUATIC LIGHTING

I am an artist by profession. I sculpt space, objects and figures with light. I am not a scientist. I am not setting out to invent a new light source. I am not testing new technologies on animals. My goal is to create a new arrangement of currently acceptable and physiologically supportive technology that can allow for a new level of flexibility in professional aquatic lighting. I pose that flexibility of lighting can offer the aquatic microenvironment the ability to visually sculpt the aquascape in a manner that is appealing to human aesthetics while still providing for the physiological and psychological needs of the aquarium inhabitants. I will create a prototype of a customizable aquatic lighting unit for manufacturing consideration. I will interrogate what it means to have a "fully customizable" aquatic lighting apparatus, by demonstrating it on three contrasting aquatic microenvironments. Each of the three environments will represent those commonly encountered in the professional aquatic field.

GOALS OF THE EXHIBITION

The overarching goal of this project is to create and display the flexible aquatic lighting prototype, and to interrogate the application of flexibility within an aquatic microenvironment, and how the prototype offers a dynamic sculpting of the aquascape. In addition, the aesthetic design of the exhibit space, and the technical layout of the aquatic microenvironments are both equally important to the overall success of the project due to the fact that the audience experience must support what is gained by having the flexibility to visually sculpt the aquascape. It is understood that the reason fish are kept is because people wish to enjoy the beauty fish have to offer. Strictly physiologically speaking, there are many pre-set lighting configurations on the market that meet the physiological needs of aquatic life. Therefore physiologically, flexibility in lighting an aquascape offers nothing new. But if it is argued that humans keep fish for aesthetic reasons, then much can be gained by adding flexibility that allows a lighting design to be created within the microenvironment. For this reason, the exhibit will be presented in an installation format. Major elements to consider when designing an installation space include room lighting, sound, and audience member movement; which will all be addressed in order to support the goal of aesthetically supporting the environment in which to demonstrate the flexible lighting prototype.

SCULPTING AN AQUASCAPE WITH LIGHT

Until the relatively recent introduction of LEDs (light-emitting diode), aquarium lighting consisted of primarily florescent and halogen/metal halide sources. These sources have always been housed in ridged shapes such as squares or circles or rectangles. Halogen and metal halide bulbs have been housed in square or circular housings, while florescent bulbs, historically, have been a long tube housed in a rectangle spanning the length of an entire aquarium. Neither one of these lighting options allow for any flexibility.

Illustration 1: Typical lighting hoods for florescent, halogen and metal halide bulbs.

Serving a purely functional role, the florescent light evenly fills an aquarium with diffuse light; much in the way the sun evenly lights the planet earth. The halogen or metal halide sources, being more a concentrated source, and hotter in temperature, have been regarded as the go-to lights for coral cultivation for their more *direct* sun-like qualities. In some cases, both a florescent fixture and a halogen fixture would be used together in an attempt to harness the benefits of both approaches. But even in this combined fixture scenario, there is very little flexibility to allow for movement of the light sources, and therefore the lighting angle at which the aquascape can be lit is limited to a typical 90 degree angle of incidence.

With the introduction of LEDs into aquatic lighting comes new light color options and sleeker housing styles. Before, with the use of florescent, halogen and metal halide bulbs, the color tones achievable were fairly limited and included cool and warm white tones in addition to several blue tones. In opposition, LEDs are available in a wide variety of colors with the capacity to mix to an even further array of colors. New on the market advanced LED units, although costly, tend to offer "sun" colors (white, amber and pink tones) and "moon" colors (blue tones). Another advancement of LEDs is the ability to dim intensity of individual colors. At the present time, all the at market LED lighting units are still limited to rectangular and square shapes just as florescent, halogen and metal halide bulbs have been, and all mount at the same historic level of a 90 degree angle above the aquarium.

Illustration 2: Example of current aquatic LED units.

Whether the absence of customizable units is due to lack of an idea of how to create flexibility, or due to a continued "attempt to mimic nature," is unclear. But if resulting from the attempt to mimic nature, the attempt falls flat when one remembers how environment affects lighting. One example from nature is how a fallen tree in a lake or pond creates a distinct (sharp) pattern of shadow; above that, a standing tree may provide a larger expanse of subtler shadows. In cave areas there are very specific concentrated rays of light that burst through cracks and around corners. It is in consideration of these elements that I approach a stage and an aquarium as two equal yet different "spaces," or, "canvases," with the potential to be sculpted with light. Most importantly, I consider how best I might sculpt the environment with respect to the aquatic life existing in that space.

It is the goal of this exhibition to challenge the current norms of block lighting for aquaria. I will take a stage design approach instead, and rather than lighting the space with a single tube fixture which provides only a general lighting option, I will light the aquascape with focused specificity.

On the stage, lighting designers manipulate angle, color and intensity to visually sculpt a figure or object, in order to draw attention, create focus, or to obscure another perception, and to influence the emotional or psychological state of an audience. Likewise, the goal of this exhibit is to design a dynamically lit aquascape that utilizes angle, color and intensity to create a beautifully composed yet physiologically sensitive microenvironment. It should also be stated that while the goal is to achieve these aspects, it will also be a priority to take into consideration the natural habitat for a given species or group of species. For that reason, when using color in this exhibit, I will limit the color source to more naturally inspired tones of whites, ambers, and blues verses colors that are overtly unnatural such as red or bright green, or any other harsh colors.

DESIGNING A HUMAN SPACE

As previously mentioned, the aesthetic design of the exhibit space and the technical layout of the aquatic microenvironments are both equally important to the overall success of the project due to the fact that the audience experience must support what is gained by having the flexibility to visually sculpt the aquascape. Also mentioned was that major elements to consider when designing an installation space include room lighting, sound, and audience member movement; which will all be addressed in order to support the goal of aesthetically supporting the environment in which to demonstrate the flexible lighting prototype. It is important to ensure that the overall human experience within the space is a positive one in which the audience is engaged on a sensory level, with an experience void of obstruction in navigation or distraction. The lighting needs to be sufficient for safely walking through the space and for easily reading exhibit related materials. While achieving these goals, the space also needs to be dark enough to not distract from the overall lighting design within the three microenvironments themselves. Striking the correct balance between lightness and darkness will be key.

Sound, being the first sense humans develop, can be argued as integral to any successful environment. The sound of this environment needs to present a sense of calm curiosity. Therefore I will collaborate with a professional sound designer to create an inspired soundscape, which will underscore the entirety of the installation.

Each microenvironment that will be lit with a prototype lighting fixture will contain an excess of 100 gallons of water (the size that should adequately demonstrate the flexibility offered by the prototype itself). Consequently, the space the exhibit is housed in must be large enough to house a minimum of 400 gallons of water while allowing for audience members to move from aquarium to aquarium in an unrestricted flow; this includes honoring The Americans with Disabilities Act (ADA).

PREPARATION

Moving hundreds of gallons of water and live animals onto a university's property is a large undertaking. Both tasks need to progress in tandem with all of the other elements of preparation, and each task requires a deep understanding of the details involved in the staging of an exhibition. An exhibit space must be procured, proper permissions must be applied for and granted, all of the physical elements of the exhibition must be determined, and an audience experience must be specifically crafted.

PROTOCOL

Any university that has status as a research facility, or more specifically that uses animals for federally funded laboratory research, must have an Institutional Animal Care and Use Committee (IACUC) that reviews and governs animal research protocols and carries out evaluations of that institution's animal husbandry. The protocols themselves are hyper specific outlines of how an animal will be cared for while in the possession of the university. Any animal controlled by a member of that university, whether faculty, staff or student must have a protocol that outlines that specific animal's care and what procedures that animal will undergo during its life on campus.

Due to the fact that fish are living, sentient animals, an IACUC protocol was necessary to instigate the process of transferring fish onto campus for this exhibition. The IACUC protocol is mentioned in this section first because it dictated every other element of the exhibition, and a basic understanding of "what is a protocol" is essential to understanding the decisions made concerning the space, inventory, species choice and other elements of the process. In fact, the IACUC protocol required that the exhibition space and inventory had to be determined prior to the protocol application filing in order to be considered as part of the protocol.

THE SPACE

The foremost need of the space was to be large enough to house the three separate habitats comfortably. Other details to consider were accessibility, availability, security, and power. In addition, it was necessary to find a room into which the Department of Theatre and Dance would be comfortable allowing hundreds of gallons of water. One room fit all of the necessary criteria: Winship B104.A. Once the space had been procured, a registered booking was required. The spaced was booked for February 26th through March 9th, 2014 and the design for the exhibition layout within the space began.

Illustration 3: Photos of B104.A Pre-installation. Photo by author.

INVENTORY

The choosing of aquarium inventory happened concurrently with the development of the design of the exhibit during the protocol process. The size and shape of aquariums proved a primary exhibit consideration. Determination of the specific aquariums was based on criteria from the following four questions. First, what size and shape of aquarium would best support demonstration of the lighting prototype? Second, would the determined aquarium sizes be appropriate for housing the types of microenvironments that I wanted to use? Third, could the aquatic systems needed to support those microenvironments be safely utilized in that space, without over taxing power capabilities? And finally, did both the size and the shape of the aquarium allow for the audience viewing and ease of movement that was desirable within the larger exhibition?

In the end I determined that the following inventory would successfully provide the components necessary and serve to demonstrate the characteristics of the flexible prototype: A standard 150 gallon aquarium measuring 72 ½" x18 ½" x 29" and two custom sized aquariums, one at 105 gallons measuring 48"x48"x12" and a second at 110 gallons measuring 24 ½" x24 ½" x12". Both custom aquariums were designed to allow for walk around viewing, while the standard 150 gallon aquarium can be viewed from three sides.

Wittke Thesis **Exhibit Hardware Inventory**

Predators
150 gal 72 1/2x18 1/2x29
Oak cabinet (32" tall) -Black w/canopy
Wet/Dry Filter
External Pump (main system pump)
Chiller
Submersible Heater
Protein Skimmer
UV sterilizer
Thermometer
2 power-heads
Live Rock
Reef Sand
Artificial Coral

Reef
105 gal 48x48x12
stand (32" tall) Black
Canister Filter
Chiller
Submersible Heater
Protein Skimmer
Thermometer
Powerhead
Lace Rock
Reef Sand
Artificial Coral

Fresh
110 gal 24 1/2x24 1/2x48
Oak cabinet (36" tall) -Black
Canister Filter
Submersible Heater
Thermometer
Holey Rock
Artificial Plants

Illustration 4: Hardware Inventory.

EXHIBIT DESIGN

The use and application of the prototype was unquestionably the central element to the design of the exhibit, however, the way in which the prototype embodied all of the goals of the project was equally important. I decided that each of the three aquariums should represent two elements. The first was to be a typical community of inhabitants that an aquarist would commonly maintain. The second was the audience members' perspective of viewing the prototype at each aquarium.

COMMUNITIES

The three communities existing within the aquariums would be saltwater predators, (not all specifically predatory, but at least having formidable self-defense mechanisms) the saltwater reef dwellers (commonly found within the safety of a reef), and freshwater African Cichlids (originating from the great lakes of Africa). These three communities would each need to be housed in the most appropriate aquarium, as previously determined by the four questions of inquiry used when preparing the IACUC protocol application.

For the sake of discussion I will refer to the first aquarium (the 150 gallon aquarium measuring 72 ½" x18 ½" x 29") as "The Predator Tank," second (the 105 gallon aquarium measuring 48"x48"x12") as "The Reef Tank," and the third (the 110 gallon aquarium measuring 24 ½" x24 ½" x12") as "The Cichlid Tank."

The rationale used to determine which community would be in which aquarium was as follows: The predators tend to be larger, therefore typically need more gallons, so since the 150 gallon aquarium was the largest, it therefore proved the most appropriate enclosure for them.

African cichlids are hardy and aggressive. They tend to be less concerned about where they swim (they do have a "level" of preference, but are more flexible) as long as they have hiding places for when they feel threatened. Therefore, the African cichlids would do well in the tallest of the three aquariums. Last, the reef dwellers were comprised of several independent species along with a group of shoaling (a species that swims together for protection and social reasons) Chromis. The flat, larger footprint of the reef tank suited it more to the shoaling activities-- in addition to being a style of aquarium conducive to coral propagation (if one were to chose to raise coral) since the shallow water depth places lighting closer to the coral, which need high intensity light.

VIEWING OF THE PROTOTYPE

I approached the design of the exhibit much like I would approach the design of a show within a theatre. I considered both horizontal and vertical space. I addressed the space from a top view, like a theatrical *Ground Plan*, and also from a horizon line, as in a theatrical *Section* (side view). Addressing the Ground Plan provided basic placement within the room and also ensured a working traffic pattern of audience members. The horizontal approach determined how the prototype would be viewed in relation to the aquarium itself. I specifically desired three viewing experiences for the audience. One viewing experience would be from above the prototype, in order to see the prototype itself. Therefore, that aquarium was required to be at a level low enough that the viewer would most likely look down on the unit at about chest level. The next view was to view the lighting from *below* the water surface, creating an experience more akin to that of a fish or at least being in the water. This "from below" view was the rationale behind the unusually tall cichlid tank. Last, I wanted to demonstrate a "typical" view as well, since most aquariums tend to be viewed from straight ahead in a "picture frame" type manner.

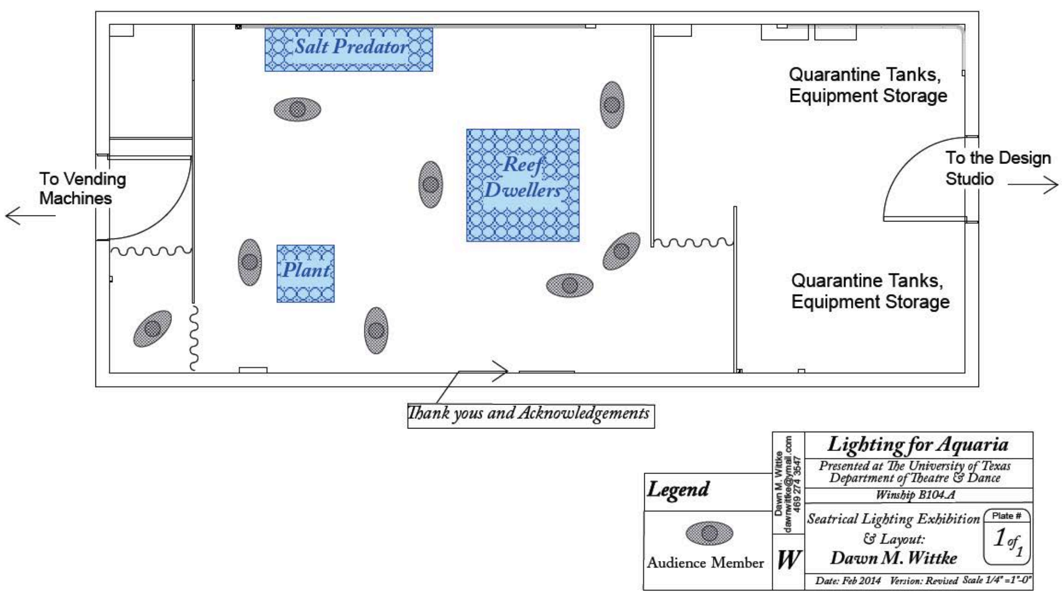


Illustration 5: Installation Ground Plan within B104.A. Drafted by author using the Vectorworks CAD drafting program.

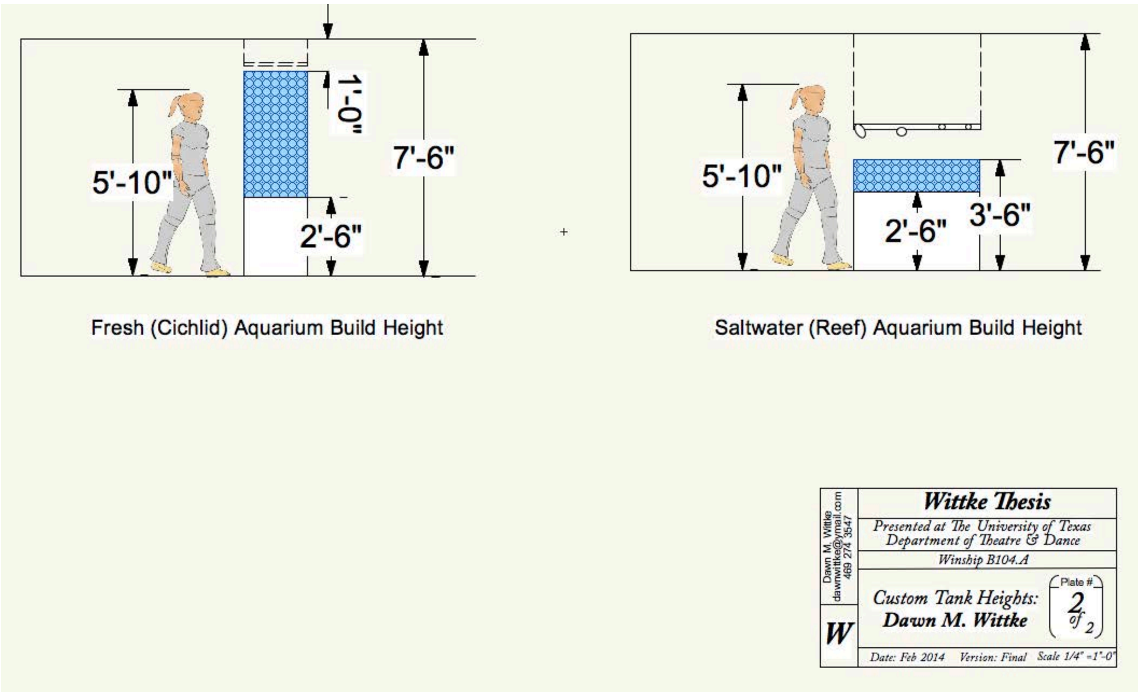


Illustration 6: Custom Aquarium Build Heights (Sections). Both Fresh Cichlid and Saltwater Reef. Drafted by author using the Vetorworks CAD drafting program.

PROTOTYPE CONCEPT

As discussed, standard aquatic lighting typically consists of a single light source or a single block of lights; therefore flexibility has traditionally been minimal. On the other hand, stage lighting design, which is highly flexible, has the ability to add texture, clarity and dimension to theatrical sets, architecture, theme parks and landscape. It seems to follow that a next logical step in making a more dynamic aquascape would be for lighting to be used in a similar manner to stage lighting in aquascape. Indeed the industry of aquarium keeping is progressing toward a design approach in lighting; the larger public aquariums and zoos have seemingly mastered the craft of artfully lighting large-scale exhibits. The increased use of LED lighting is swiftly changing the way aquariums are being lit in all scenarios, but still, complete flexibility has not been achieved. In creating this prototype I intend to interrogate how complete flexibility might be achieved, and if achieved whether or not it would be successful in a private, professionally designed and maintained aquarium. It should be noted that the type of aquarium to which I am referring is an advanced system, with cost associations more applicable to aquariums of a "show" quality. Even more specifically, I suspect its application in saltwater and other specialty aquariums that exceed 100 gallons.

It is necessary to discuss exactly what the properties of "flexibility" are in lighting design and what that will mean in this aquatic lighting application. Next, focusability, placement, pan and tilt, color and intensity will be discussed. These elements in turn determine the physical aspects of the prototype concept.

THE LIGHTING DESIGN APPROACH

WHAT IS FLEXIBILITY?

As a lighting designer, I seek to sculpt people, objects and places with light. I consistently look to the qualities of angle, color and intensity to help achieve these objectives. Without flexibility though, none of these qualities are achievable. Next I will discuss the attributes of flexibility within lighting design.

FOCUSABILITY

In the theatre, we refer to "the focus" of each individual lighting fixture used within a design. That "focus" is the sum of placement, pan (side to side directionality), tilt (up and down directionality), and lens degree (ability to determine the spread of a given light source). It allows us to "sculpt" the space, to "carve out" an object or give dimension to a figure through the use of angle and selectivity. Employing these attributes we have the flexibility to either showcase or obscure parts of the set, actors/dancers, objects, and architecture. Without the ability to "focus" individual light sources according to those parameters, there exists a lack of focusability.

PLACEMENT

First and foremost, placement is of a critical concern. How can a "block-type" lighting unit approach be avoided? As mentioned in "Sculpting an Aquascape with Light," "I began to think of a stage and an aquarium as two equal yet different "spaces."' So, it seems natural for me as a designer to devise a stage like lighting grid system that would employ the use of independent locations on which to place individual LED light sources. In this scenario, I could place a unit literally anywhere above the water, with any desired distance or lack of distance between sources.

ORIENTATION (PAN AND TILT)

Pan (side to side movement) and tilt (up and down movement) are considered often the next attribute of focus. If a LED can be placed above the water, and tilted slightly upward so that the angle of incidence changes, then angle can be manipulated according to need. As an example: an object such as a coral could be selectively lit from a 45 degree angle vs. the typical 90 degree angle.

COLOR

Color is the next attribute to be considered. Color is commonly believed to "set the mood" of an environment. In the aquarium industry, white or amber lights have become accepted as "daylight" colors, while blues tend to be accepted as "nighttime" colors. I tend to think of bright cool lights as daylight, and warmer less intense lights as twilight colors, and some blues as "nighttime blues." My thinking is based on actual observations of the natural world, and it is my opinion that most blue LEDs on the market are not particularly natural looking, although more natural than reds and greens. Pink tones have also gained popularity with coral keepers because the color can act to pull out color accents in some species of coral. For the sake of this prototype, I will limit the color palette to white, amber and blue type LEDs.

INTENSITY

It should also be mentioned that intensity plays a large role in visually sculpting an object. The same color used at two different intensities can cause the color to appear to be varied and add dimension to a shape by causing shadows or accenting the form. Therefore, having control over the intensity of the individual LED sources is equally important to having control over color.

THE PROTOTYPE UNIT DESIGN; ACHIEVING FLEXIBLITY

Looking to achieve these attributes that will create a fully flexible lighting unit, I began to look at the practicality of actually designing a unit. I wanted to consider all elements, so as a starting point, it was necessary for me to determine if flexibility of lighting could be as achievable and beneficial within water as it is in air.

ADDRESSING THE ISSUE OF WATER VS AIR

Obvious enough, water is a different medium from air, being a denser medium. When thinking about using light in water, there are known differences to consider such as density and surface movement. For this reason, the first step in creating a prototype is to determine what needs and limitations for a "lighting design within water" exist. In order to make these determinations, a series of test photos were taken to document lighting characteristics within water, including intensity, diffusion and directionality. The investigative photos were taken in the same location, with the same camera in the same position in a controlled lighting condition. All photos were taken of the same aquarium, with different water conditions. In order to ensure consistency of light, all photos were taken at night to ensure no variance of sunlight could penetrate any window. Photos were either taken in complete darkness, or with one indirect ambient light source not pictured. That light source also remained constant. Lighting tests were conducted in the following conditions: freshwater, freshwater aerated, saltwater, and saltwater aerated aquariums. For each series of photos I started with a standard LED aquatic lighting unit as a baseline (the typical long rectangle), and then transitioned to various LED sources from there.

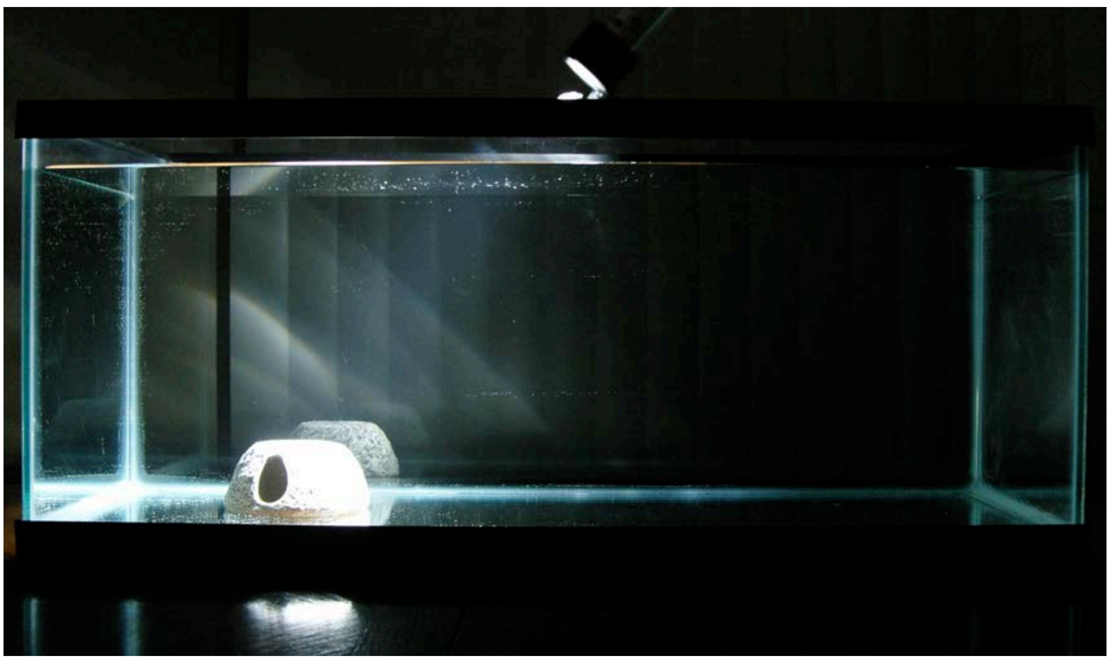


Illustration 7: Example of Control test for lighting within water.

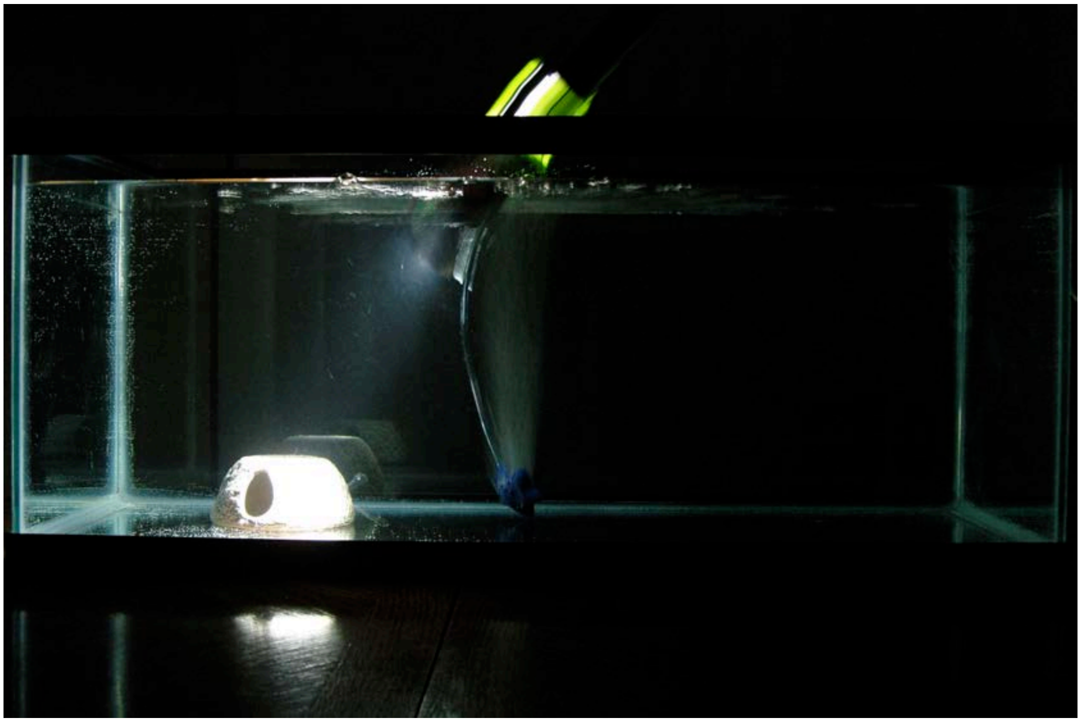


Illustration 8: Example of Control test for lighting within water with aeration and surface movement.

There is also the fact that water and electrical components must be kept away from one another for the purpose of safety. For this reason, any lighting used to light water must be maintained above the water level. (Submersible LEDs do exist, but that is not the purview of this thesis.)

ACHIEVEMENT OF FLEXIBILITY OF PLACEMENT

Employing the idea of a traditional theatrical grid, I began to work with the idea that the prototype could repeat the grid format made from a series of "crossbeams" creating a checkerboard pattern across the top of an aquarium. The grid structure would provide flexible positioning for the individual LED fixtures. Although the grid structure created new opportunity for fixture placement, it still proved somewhat restrictive to have a specific grid that would have to be adhered to.

A solution to the restrictive grid could include construction of differing models, some with a more densely arranged grid. Or, an even better solution would be to add more flexibility to the grid itself. I began to consider the idea of independent grid components that could be customized to fit differing aquarium shapes and sizes. I decided on independent, yet interlocking "battens." (A batten is a long thin piece of wood or metal that is used to connect and support other pieces of wood or metal. Battens have applications in construction, in sailing and in stage lighting among others.)

I determined that to harness the total flexibility this system could have to offer, a variety of battens would be chosen and configured. These "independent yet interlocking battens" would then be placed in a chosen "slot" on a surrounding frame, or on more independent battens. This frame could run the entire length of the individual aquarium, or an appropriate length within the aquarium, and would be present on both sides. Each batten must lock into this frame on each end, creating a ridged "I" intersection. The level of customization would then be determined by design through choice of the placement of battens and the number of battens used. Next, it would be up to the Lighting Designer of the aquascape to determine the exact placement of individual LED fixtures on the existing battens.

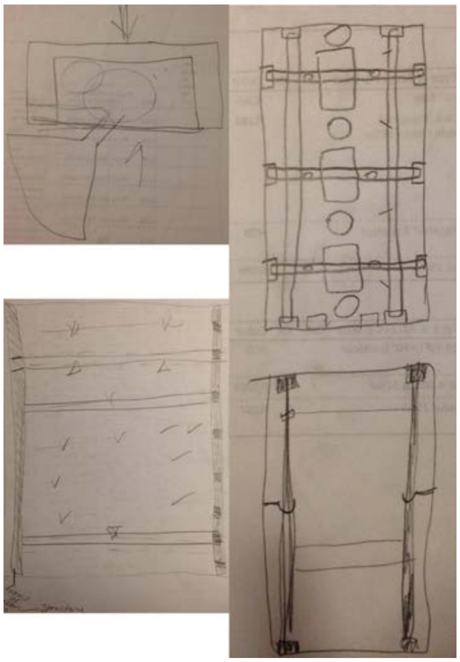


Illustration 9: Earliest Preliminary Design Ideas of Lighting Unit.

ACHIEVEMENT OF FLEXIBILITY OF ORIENTATION (PAN AND TILT)

The next attribute of flexibility to consider is pan and tilt, which will allow variable focusing angles. If the LED light sources are not permanently attached to the battens, but rather have the ability to pivot, twist and even stretch (or telescope in some manner), then any above the aquarium angle is achievable. My original design was to have a series of 3 LED fixtures per batten. The LED fixtures could each slide back and forth on the batten according to lighting needs. This option, however, by limiting the number of LED fixtures per batten, did not offer complete customization of the grid. The only way to achieve complete flexibility was to eliminate limits on LED fixture placement and number.

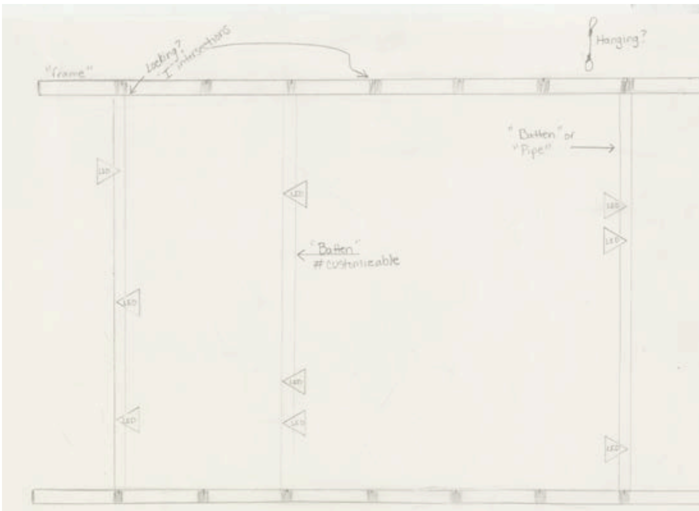


Illustration 10: Early Design of Lighting Unit.

ACHIEVEMENT OF FLEXIBILITY OF COLOR

Color flexibility with modern LEDs is an easy task. There are hundreds of suppliers of LED lighting components and pre-assembled LED lighting units. Options for color choice and/or temperature is vast. I will reference back to the fact that not all available LED colors are natural or physiologically supportive to life. At this point, it becomes an ethics and animal husbandry issue, dependent on good choices by the designer.

Illustration 11: Examples of LED colors.

ACHIEVEMENT OF FLEXIBILITY OF INTENSITY

Intensity control of the LED fixtures is an attribute that is slightly more difficult to achieve. LEDs have specialized power needs that differ from typical light bulbs. Component LEDs, which offer the flexibility needed for this project, require either resistors or drivers to convert (or "step down") the amount of current that run through the LED. I first set out to use resistors on basic 3mm and 5mm component LEDs, but soon realized that the intensity was too low, and soldering the resistors was an unnecessary consumption of time. For these reasons, I changed over to high intensity output LEDs in combination with drivers. I decided to utilize a combination of driver types, and decided on two main systems, one driven by potentiometers, and the other by a miniature lighting console. The console would give complete intensity flexibility from zero to 100 percent, while the potentiometers would give flexibility from 15 to 100 percent.

Illustration 12: Example of LED Drivers.

THE DESIGN

The culmination of all the desired attributes: flexibility of placement, angle, color and intensity, resulted in a series of interlocking battens to be assembled in an array of configurations to create a flexible aquatic lighting unit for use on any size aquarium.

MATERIALS AND CONSTRUCTION

Construction started with the creation of housing that could be used on individual LED sources if determined to aid in focus by the designer. Having housing as an option could be used to restrict the spread of the light beam either in conjunction with, or instead of, lenses on individual LEDs. Through testing of possible materials, I determined that simple aluminum cans offered qualities that fulfilled the need of being readily available, cost effective, pliable, easy to work with, easily painted, and customizable. The thin aluminum was a good solution as housing for several of the LEDs, but not the correct solution for every LED used due to the specific shape of light that it created. In several applications the housing was beneficial and employed in the final lighting design of the aquascape, and as I was able to utilize lenses on many other LEDs therefore there was a mix of LEDs with housing and LEDs without housing. The lenses used ranged from creating 15 degrees of light to 65 degrees of light and created beams of light that were either circular or oval in shape and that had a soft edge to the beam. The aluminum housing, in contrast, created a beam of light that was a rectangle in shape, and had sharp edges.

Illustration 14: LED housing constructed from aluminum cans.

Illustration 15: Example of various lenses

Next began the process of assembling and soldering the LEDs onto heat-sinks in a circuit in a series (one LED followed by another, connected by wire). Assembling in this manner would allow for flexibility between the LEDs by not restricting the placement of LEDs on the battens to a specific set distance apart. In connecting the LEDs I chose wire that was longer than the batten itself to insure the LEDs could be moved without obstruction from the wire. Each LED was either wired in a series circuit, or wired individually. On each LED or leading LED in a series, a specific driver was employed. Each driver required a power source, and in order to have control of lighting intensity, a dimming component was needed. I utilized both a mini lighting consul with six separate channels, and potentiometers for either individual LEDs or for less than 4 LEDs in a series.

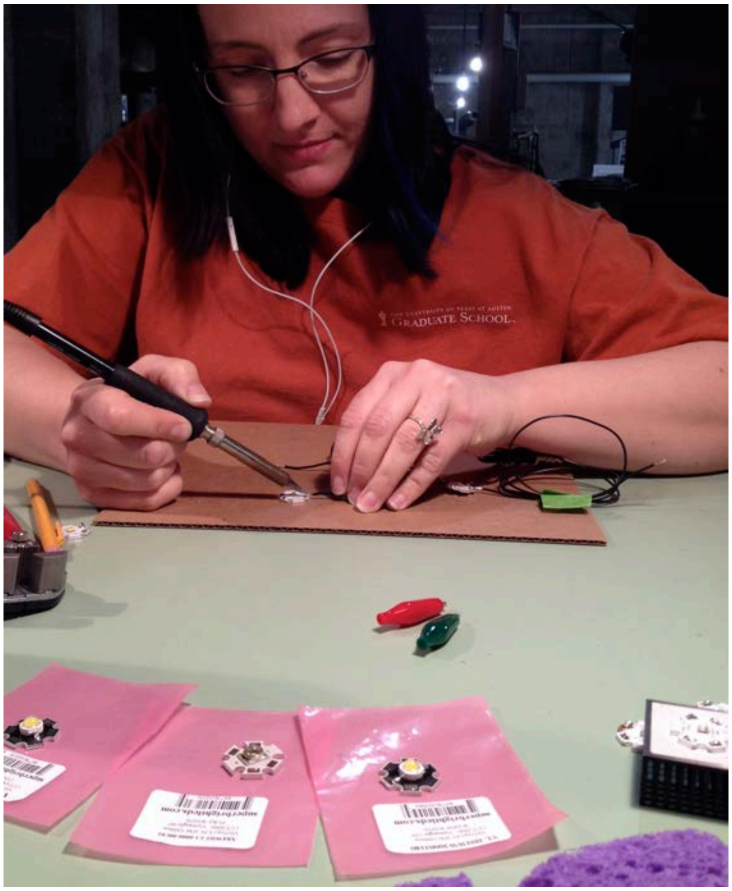


Illustration 16: Soldering a “star” high output LED.

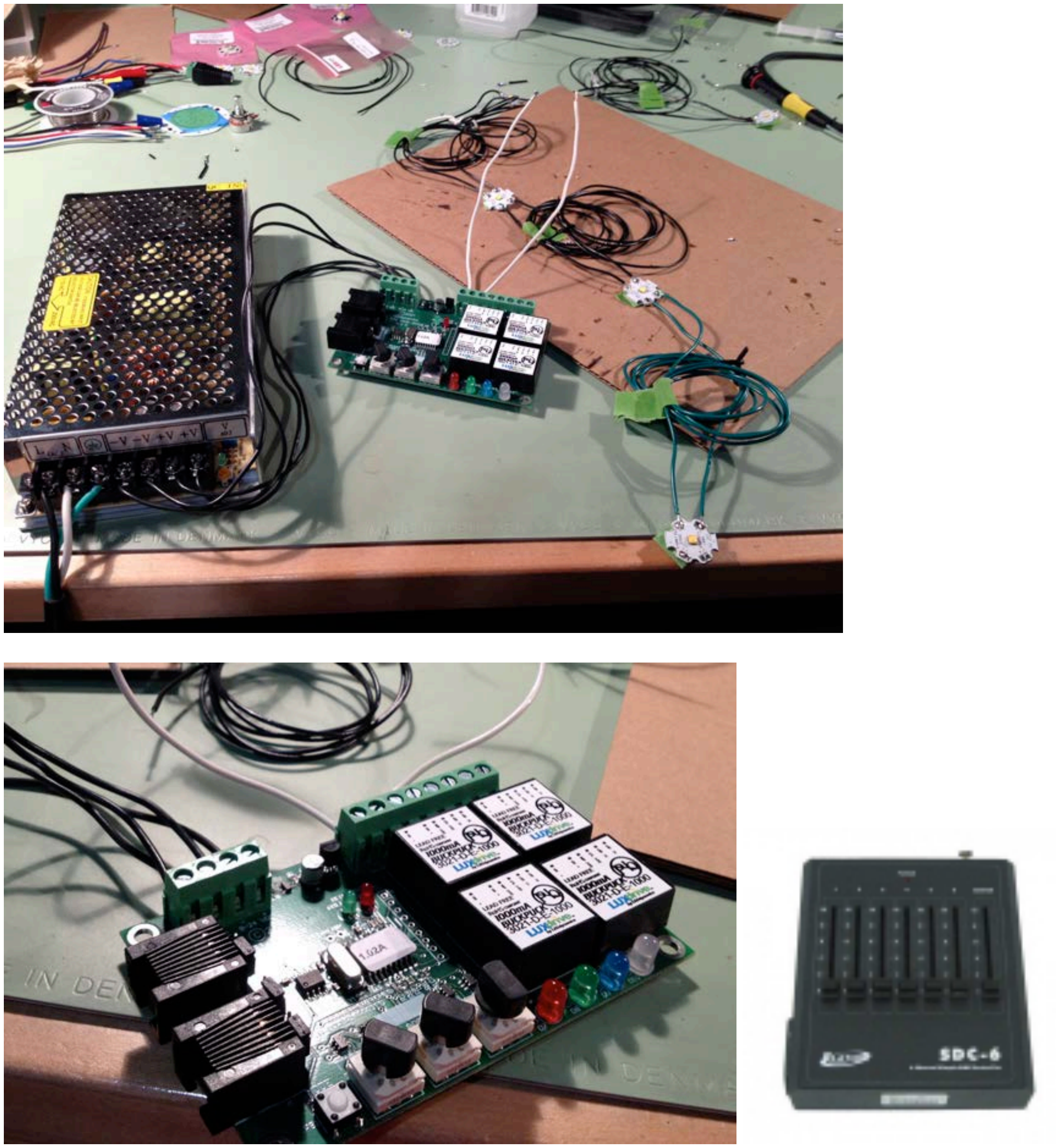


Illustration 17: A driver systems used, with power supply and mini-consol.

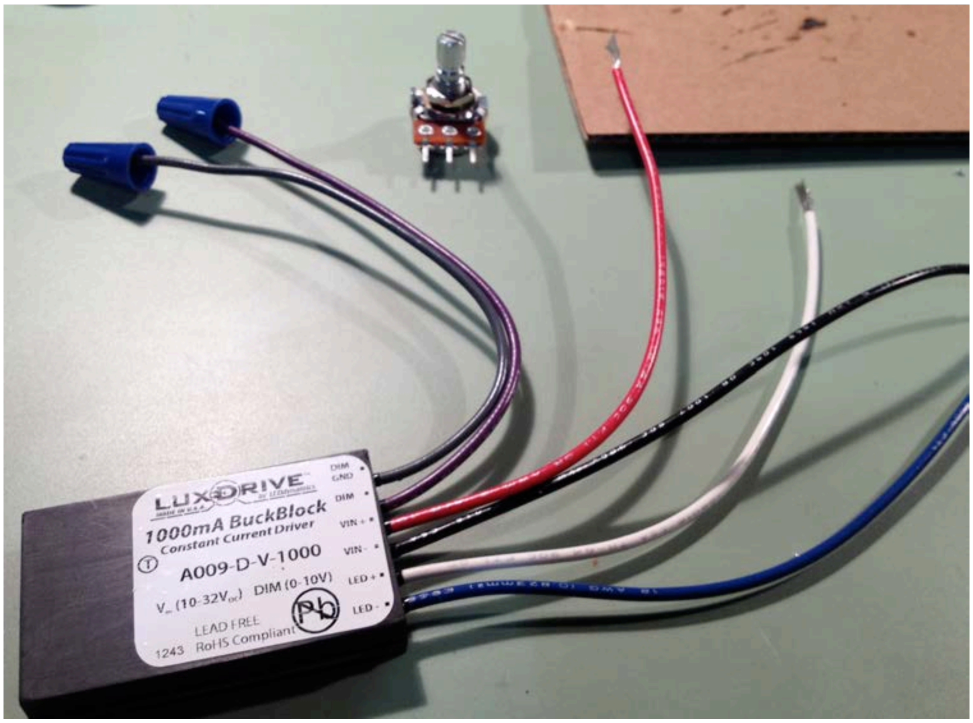


Illustration 18: Another dimming system used on the exhibit, a driver with potentiometer.

For the construction of the battens, wood proved a poor option due to the high humidity levels associated with aquariums. Most ridged metals proved difficult to work with due to the need for extensive drilling and cutting. I finally found an unlikely yet effective batten option in the use of track shelving rods. They functioned as a ridged bridge between two other tracks and could "lock" into one another by sliding one down the inside track of the other. For the sake of this exhibit, it was necessary to use a zip-tie at the point of connection between the two tracks, so going forward in the development of this prototype I will look into higher quality and higher reliability connection options.

Illustration 19: Final unit above the reef tank.

Illustration 20:   “Battens” in use above the reef tank.

EXHIBIT AND CONCLUSION

THE EXHIBIT

BUILDING A TEAM

The title "*Seatrical Lighting*" was discovered for the prototype and exhibition event in collaboration with William "Shawn" Bender. The main collaborative element of *Seatrical Lighting* consisted of Shawn Bender, and myself who served the role of professional liaison, coordinator of aquarium inventory, transport manager for all equipment and fish, and as a general collaborator on the project. Aquatic Design aquariums LLC in Plano Texas generously loaned the saltwater fish and The Texas Cichlid Association generously loaned the African Cichlids.

Sound design and engineering were entrusted to Jared Le Claire. Jared and I collaborated to create the most appropriate tone and mood desired for the installation. We also determined appropriate sound levels to assist in cancelling out external noise specific to being in the Winship building. The content of the soundscape design served to support the relaxing environment created by the overall exhibit.

The remaining team members included Rachel Bennick (technical direction) and Lauren Gallup, Malori Carr, Maegan Wilson, Terrance Mitchel and Julie Maury, who all served as general crew, primarily helping to build and install the exhibit, and as assistants in the build of the prototype.

THE EVENT

Set up of the exhibition space began on Wednesday February 26th 2014. The installation began with the placement of false walls that had been built in advance. The walls served to shape the designed space within the open room. The remaining set up commenced once the designed space had been constructed. That set up included installing sound equipment and speakers, placing room lights, hanging curtains, and mounting informational materials, among other exhibition space detail completion.

The delivery of aquariums, aquatic life support systems, and fish took on Saturday March 1st 2014. As predetermined, the three aquariums containing contrasting fish microenvironments were successfully assembled. Above each aquarium, a configuration of the prototype was constructed and a lighting design was created for each microenvironment.

On Sunday March 2, 2014 I held a *By Invitation Only* reception to open the exhibit.

Illustration 21: Opening reception on March 2, 2014.

Illustration 22: Opening reception on March 2, 2014.

Just prior to the opening, the exhibit was challenged by a faulty LED element. I believed the failure to be the driver on the main prototype system. This specific driver was intended to run all the LED fixtures for the entire predator tank, and half of the LED fixtures for the reef tank. This system had been tested successfully prior to the exhibition; however, the length of testing time had not been significant enough to indicate warning of a malfunction. Slowly the temperature of the drivers rose to an unsafe level causing the drivers to melt at their contact points. A solution was found by using more of the LED fixtures that had been constructed with the aluminum can housing, due to the fact the LEDs that I used to place in the housing utilized a built-in driver. The draw back to the housing specific LED fixtures, however, was a lack of dimming capability. As a second solution, a spare driver powered by an impromptu power source was employed for use on the reef tank. This adaption of the system proved successful. On Monday March 3rd, 2014, the manufacturer of the drivers overnight delivered new drivers, also believing them to be the point of failure, but when the new drivers arrived and were tested on Wednesday 5th, 2014, the same issue occurred, this time more swiftly and obviously. This led to the diagnostic that the system failure was actually caused by a power supply that was faulty. At this point it was too late to receive a replacement power supply and driver system, so a replacement power supply and a couple other alternate driver solutions were employed. One solution included a DC input only driver, with a 12-volt battery to run four additional LED sources. Other solutions included switching out the lenses on existing LED fixtures and trading out LED fixtures types rather than adding additional LED sources to the prototype, as had been the original plan. Ironically, the malfunction actually served to prove the flexibility of the prototype due to the fact that I could adapt the design quickly and effectively with a variety of solutions.

SUCCESSES & CONSIDERATIONS FOR FURTHER DEVELOPMENT

One of the most tangible successes came in the form of audience reaction. It was not surprising that people enjoyed watching the fish; what was surprising though was the fact that many audience members specifically cited lighting in their comments and feed back as part of what had affected them.

"Thank you for sharing this beauty and delight. I feel like standing taller, dreaming bigger, and taking a deep breath. Oh how light matters." -Megan Alrutz. "This is such a beautiful installation! It truly makes one think of how every walk of life can be seen as a stage… -Laura Rogers. "Incredible displays! I am so fascinated by the implications of this lighting approach for the big names—Seaworld…" –Ryan Belock.

Proving the flexibility of the prototype, and the usefulness of that flexibility, was also a definite success of the exhibit. Displaying the prototype in three different configurations, on three contrasting microenvironments to prove that flexibility was integral to that success by giving 3 concrete, autonomously functioning examples. Demonstrating the ability to visually sculpt rocks and plants as one might sculpt a work of art or a piece of scenery compelled the audience to think about lighting in aquariums differently than they had before, and perhaps might have even compelled them to think about how lighting in general effects our experiences. Below is an example of each microenvironment with the prototype in use. More examples can be found in the appendix. (Appendices D - F)

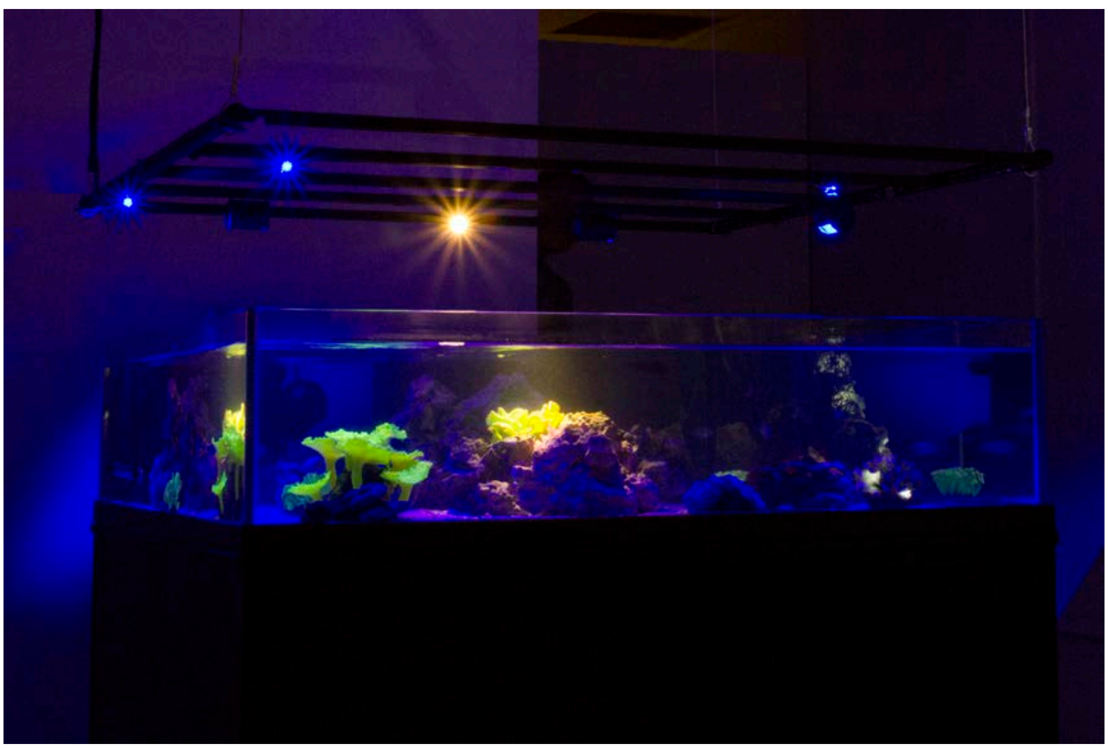


Illustration 23:   Saltwater Reef tank with lighting prototype in use.

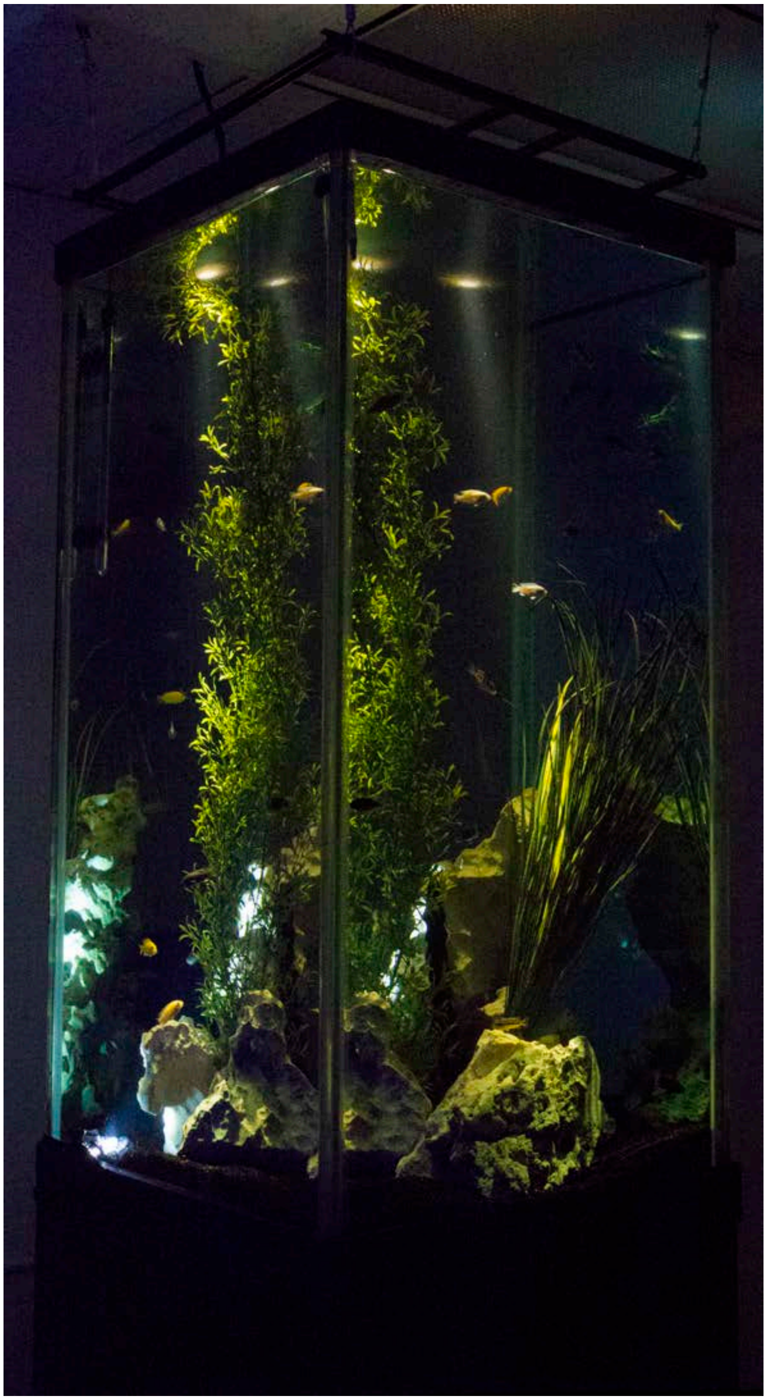


Illustration 24: Fresh African Cichlid tank with lighting prototype in use.

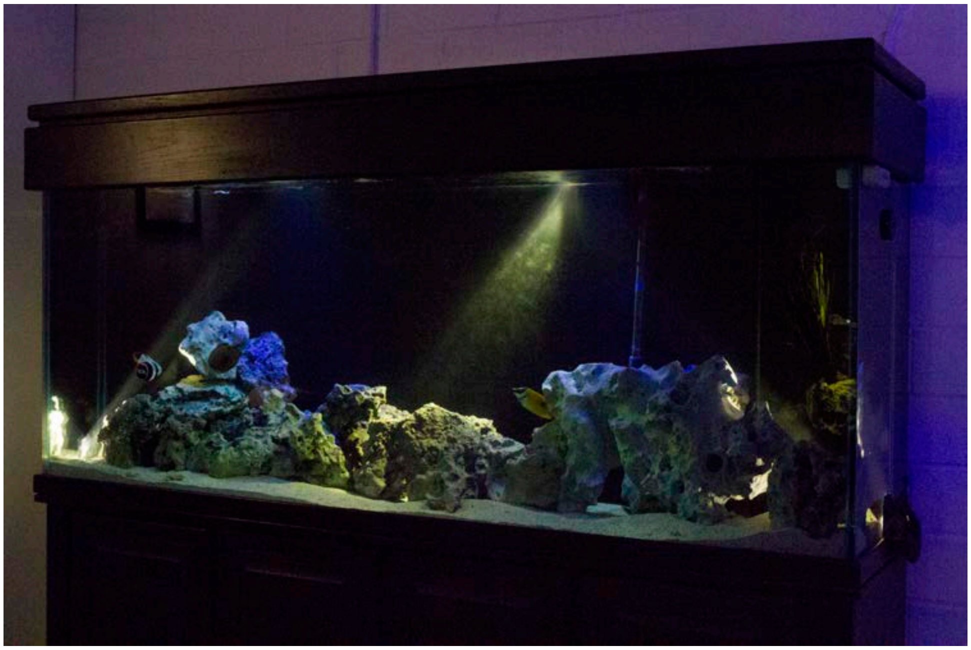


Illustration 25: Saltwater Predator tank with lighting prototype in use.

Despite the fact that the major power supply failed, the design held up once alternative solutions and adaptations were made, due to the fact that the overall flexibility allowed the lighting to still be executed through other approaches. The fact that the lighting design within the aquariums was achieved regardless of loosing an entire system also reinforces the benefits of flexibility.

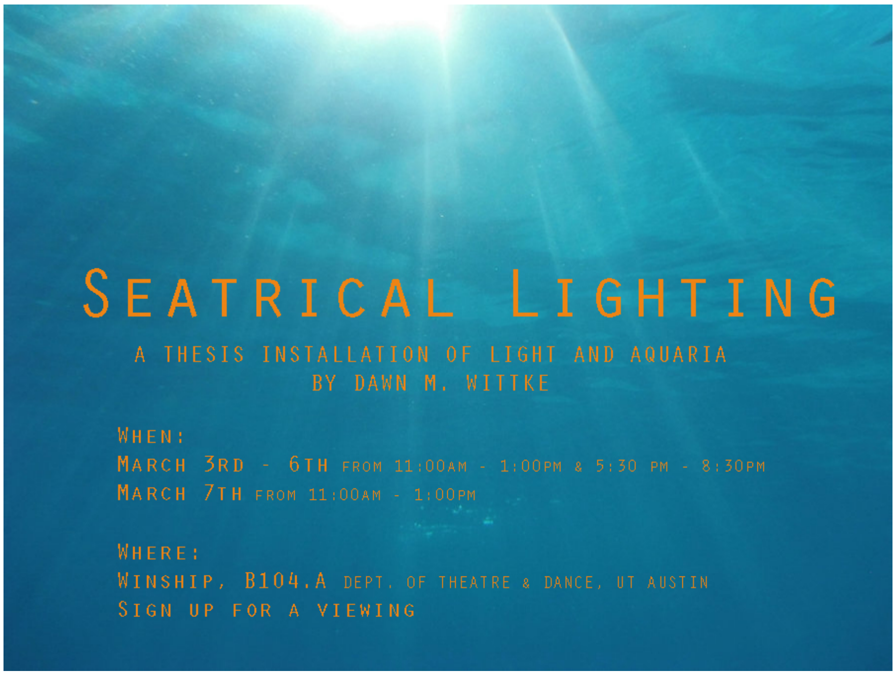
Of course, there were several elements that proved less than successful. For example, the wiring length between each of the LED fixtures did not consistently prove to be the most appropriate length for every desired application. At times it was too long, resulting in the need to coil and hide the excess, conversely, it was also too short on occasion. In future generations of the prototype, it will be necessary to find a way to design a wiring system that applies clean and exact wiring to the construction of each component system. The second element that needs improvement is the pan and tilt feature. I intended to use a pliable, yet shape-retaining wire to mount the LEDs to the battens in a manner that would allow for the LEDs to be tilted up and down and paned from side to side. Two types of heat-sinks needed to be employed on the system, however, and both footprints of heat-sink were too heavy for the wire to prove effective. As discussed, pan and tilt are integral attributes to focusability, and to move forward on any flexible aquatic lighting unit, means the need to find a solution to insure complete focusability A ball and socket joint appears to be a potential solution to ensure this rigidity yet flexibility that must exist on each and every LED fixture of the flexible aquatic lighting unit.

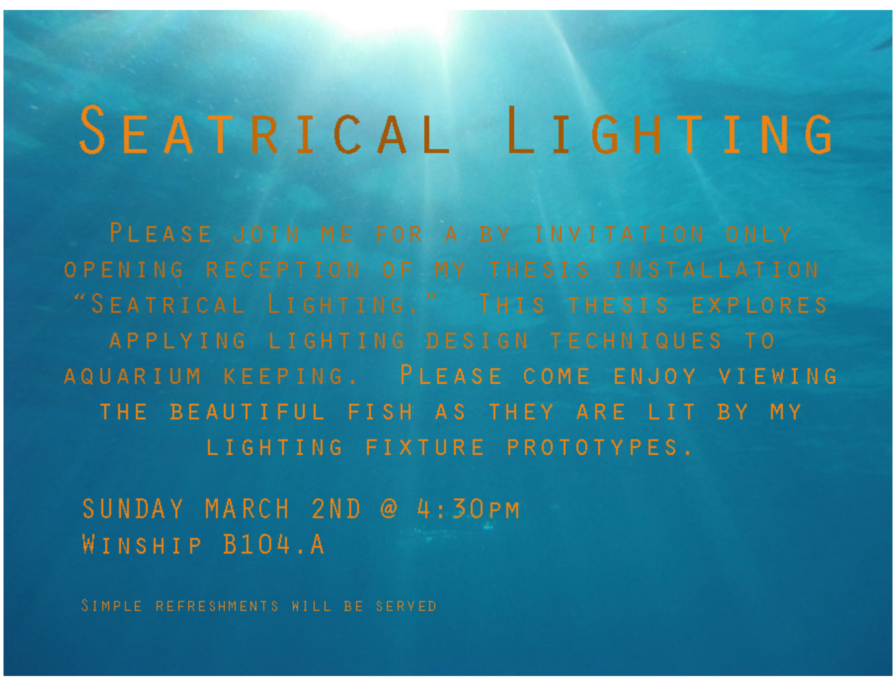
The purview of this thesis argument was the development of a professionally advanced aquatic lighting fixture that could offer more flexibility than is currently available in the professional aquatic lighting field. Further, the purview was to investigate how the flexible fixture could enhance aquatic microenvironments through application of a design approach that would utilize that flexibility in order to create a visual composition. A rewarding indicator of the success of the visual composition was evidenced in audience commentary both written and verbal. I am grateful to have been able to share the creation and demonstration of this aquatic lighting prototype with a live audience because the reactions of individuals are a more genuine benchmark of success than sterile testing environments could ever hope to be. People experience edification from watching the beauty of fish, just as they do from experiencing a work of art. The only gauge for determining if those two should be combined into a living composition is by the reactions of people.

The ability to visually compose the canvas of an aquascape as I would a stage is deeply gratifying to me as a theatrical design artist who happens to love fish. Knowing that I successfully proved the effectiveness of achieving aesthetics with light while physiologically supporting the living inhabitants of the microenvironment is going to play a key factor in further development of the lighting fixture. Now that the value of a unique flexible system is known, owning the shortcomings of my attempts during this first step will also prove to be a major element to the continued development of the prototype as it moves into the next step of the development process in the future.

Appendices

Appendix A: Promotional Documents for "Seatrical Lighting" Exhibit.





APPENDIX B: "SPECIAL THANKS" DOCUMENT.

IN COLLABORATION WITH
WILLIAM S. BENDER

IN LOVING MEMORY OF
FRED AND RAYETTA WITTKE

THE SEATRICAL LIGHTING TEAM:

RACHEL BENNICK
MALORI CARR
LAUREN GALLUP
JULIE MAURY
TERRANCE MITCHEL
MAEGAN WILSON

SOUND: JARED LE CLAIRE

FISH IN KIND DONATION BY

AQUATIC DESIGN AQUARIUMS LLC
AND
THE TEXAS CICHLID ASSOCIATION

SPECIAL THANKS:

DFW AQUARIUM SUPPLIES INC.
BRANT POPE, SUSAN MICKEY AND
THE UNIVERSITY OF TEXAS DEPARTMENT OF THEATRE & DANCE
THE DESIGN FACULTY & STAFF OF THEATRE & DANCE
MICHELLE HABECK, LIGHING DESIGN & THESIS ADVISOR
DR DANIEL I. BOLNICK, INTEGRATIVE BIOLOGY
JUSTIN A. MCNULTY, OFFICE OF RESEARCH SUPPORT
THE UNIVERSITY OF TEXAS VETERINARIANS
BEN FEST AND THE DEPTARPMENT FRONT OFFICE STAFF
HERB WOERNDELL AND THE ZONE 2 MANAGEMENT TEAM
JERRY ACUFF, LARRY RESCH, BRYAN & JOYCE BENDER,
ANDREW CARSON, REBECCA & FRED WITTKE, TIMOTHY MILLER,
CAROL & RAYMOND BENDER, DREA OILVARIES, JEFF ELLINGER,
AND AUSTIN SHIRLEY

APPENDIX C: PHOTOS OF EXHIBIT.

Exhibit photo A

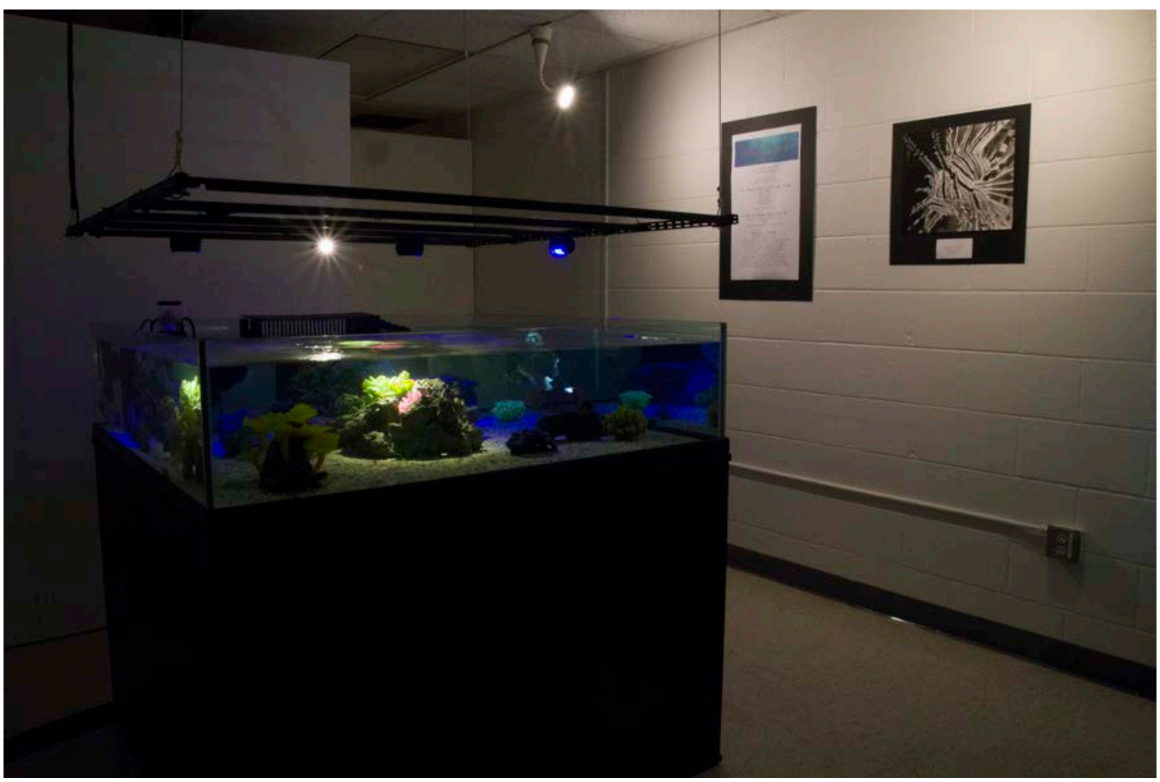


Exhibit photo B

Exhibit photo C

Exhibit photo D

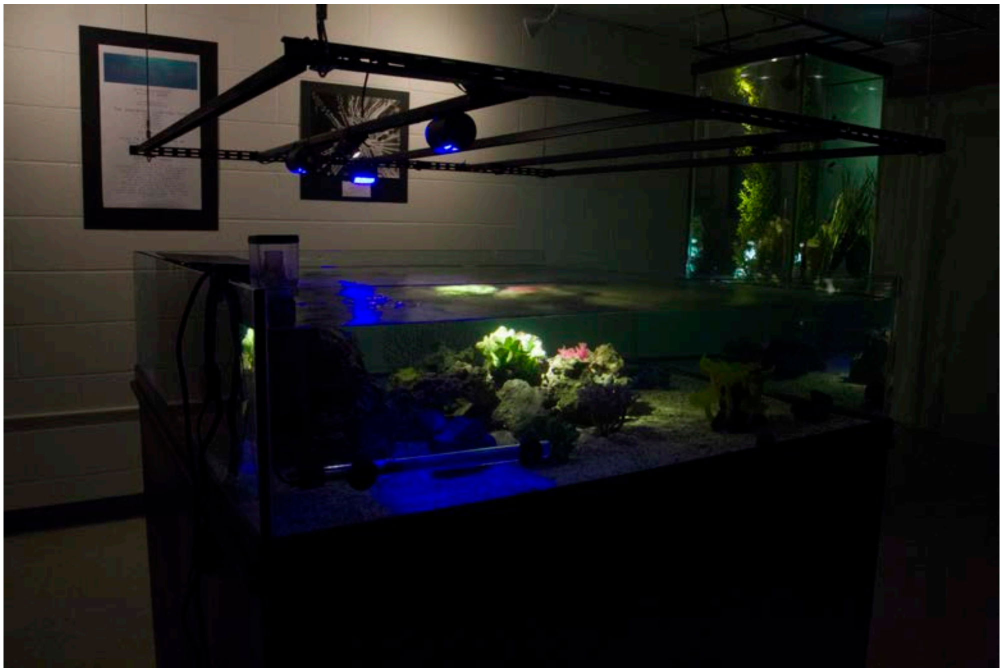
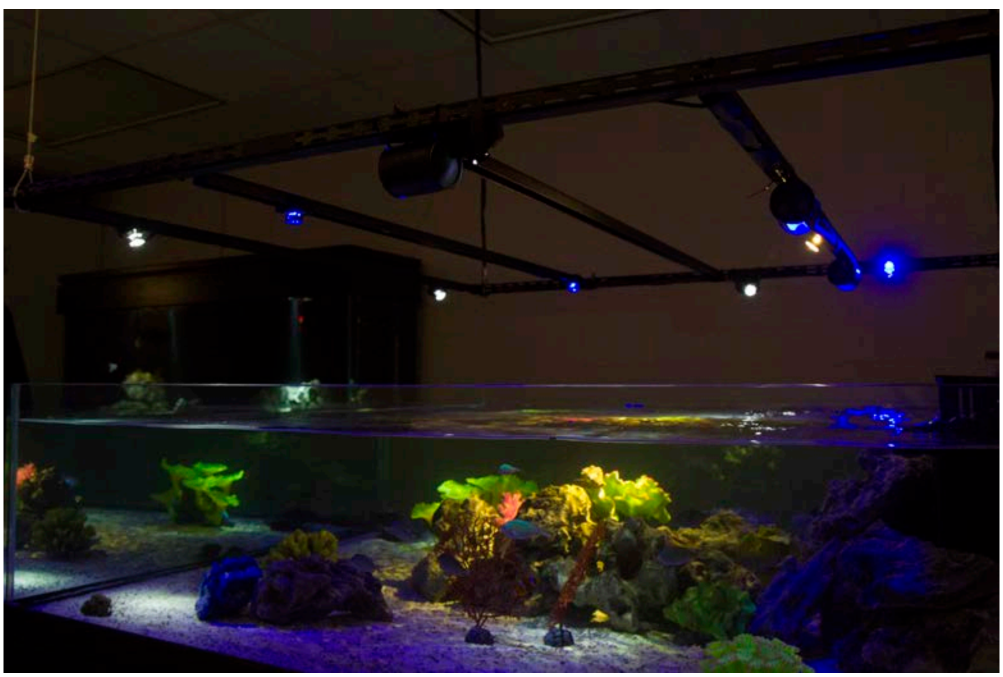


Exhibit photo E

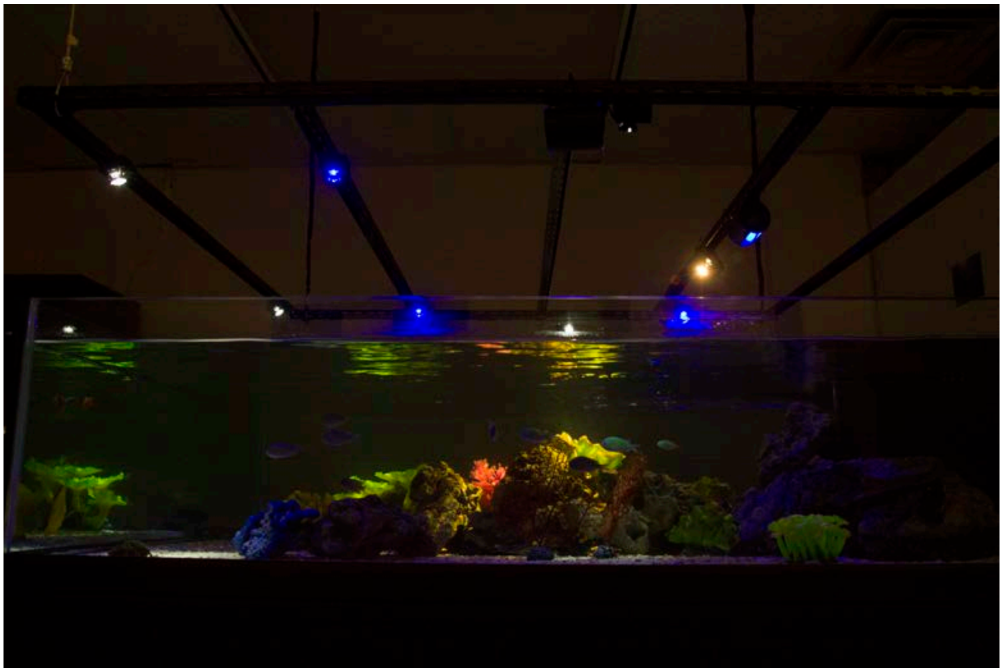
Exhibit photo F

APPENDIX D: PHOTOS OF SALTWATER REEF MICROENVIRONMENT WITH PROTOTYPE DEMONSTRATION.

Reef photo A: Right side-angle twilight (below unit)
Reef photo B: Right side twilight
Reef photo C: Front above twilight
Reef photo D: Left side twilight (well below unit)
Reef photo E: Right side-angle twilight (level to unit)
Reef photo F: Semi-close up twilight
Reef photo G: Front Semi-Above bright-night with highlight
Reef photo H: Left diagonal bright-night with highlight
Reef photo H: Left front-corner bright-night with highlight
Reef photo I: Semi-close up bright-night with highlight
Reef photo J: Close up bright-night with highlight
Reef photo K: Left close up bright-night with highlight
Reef photo L: Left side deep-night with twilight
Reef photo M: Crab close up moon deep-night
Reef photo N: Left side deep-night with highlight texture
Reef photo O: Left side deep-night semi-close with highlight
Reef photo P: Right side-angle morning twilight transition
Reef photo Q: Close up crab morning twilight transition
Reef photo R: Ambient with low level accents.

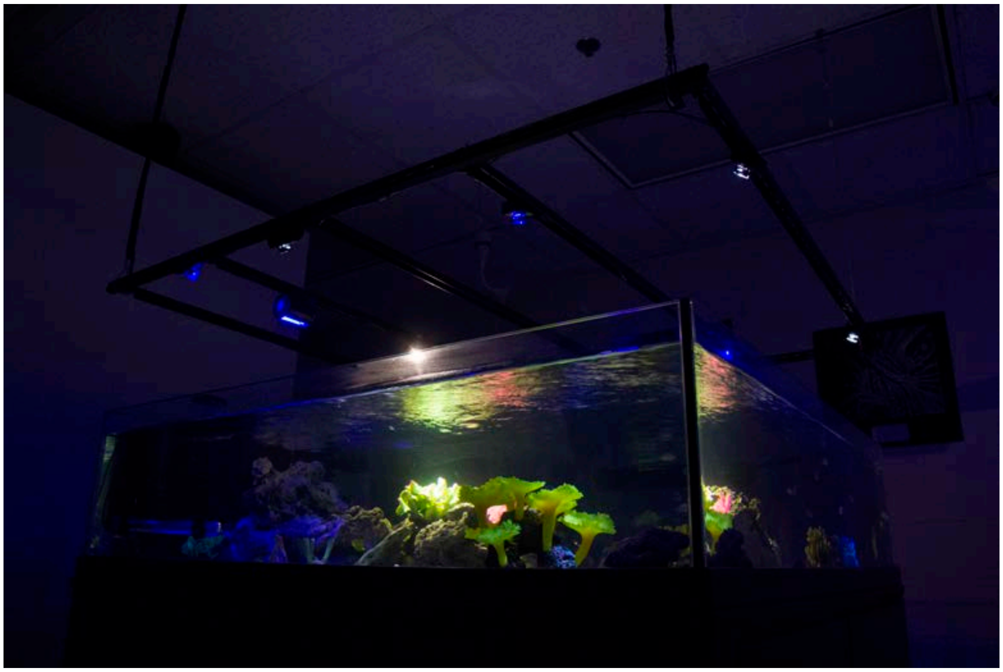


Reef photo A

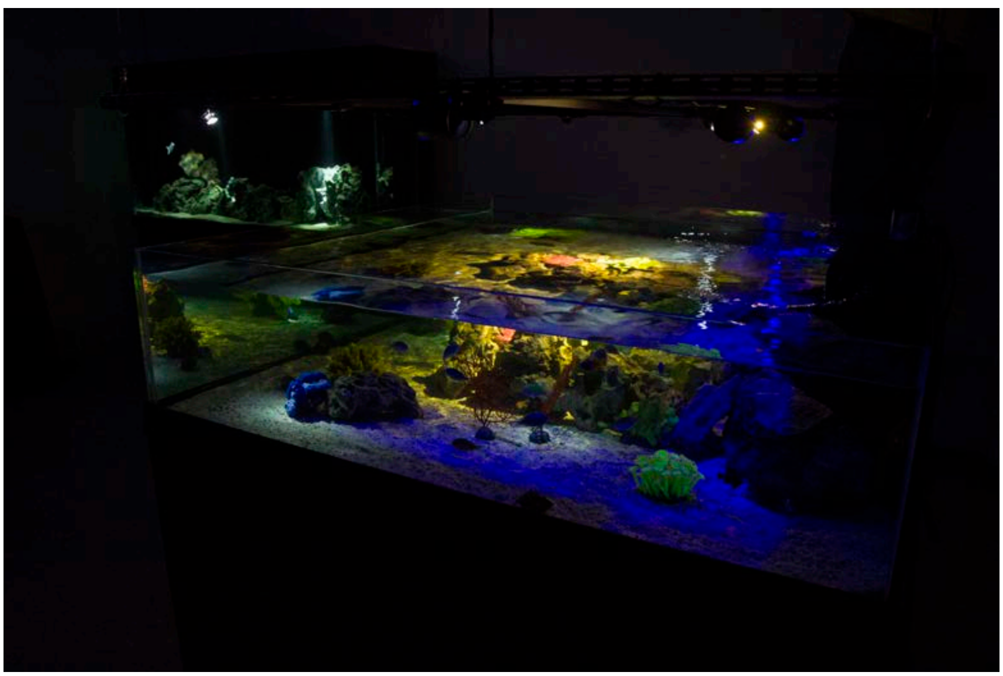


Reef photo B

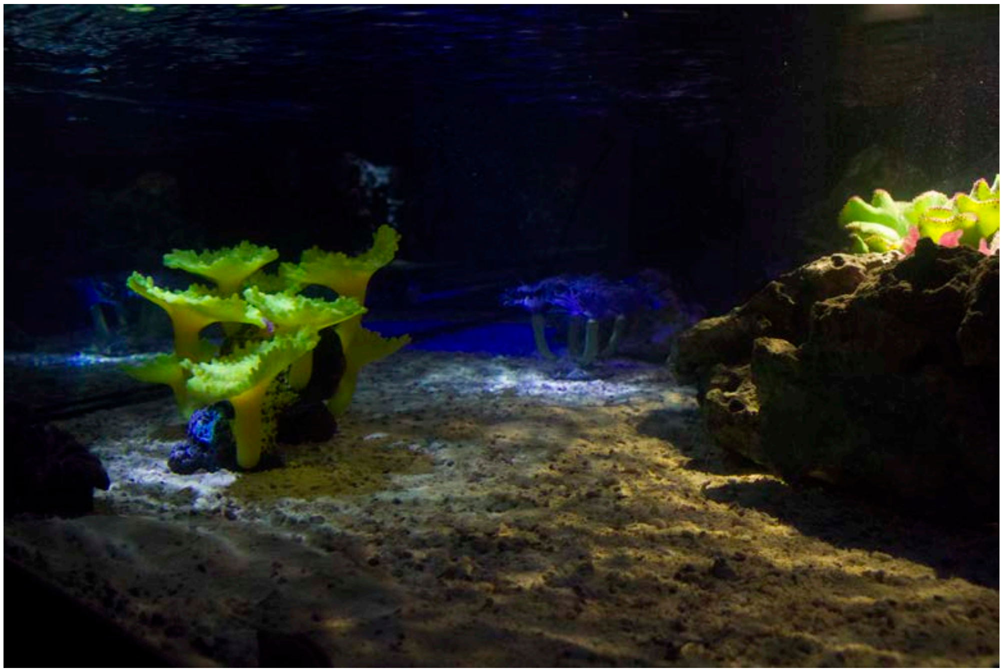
Reef photo C



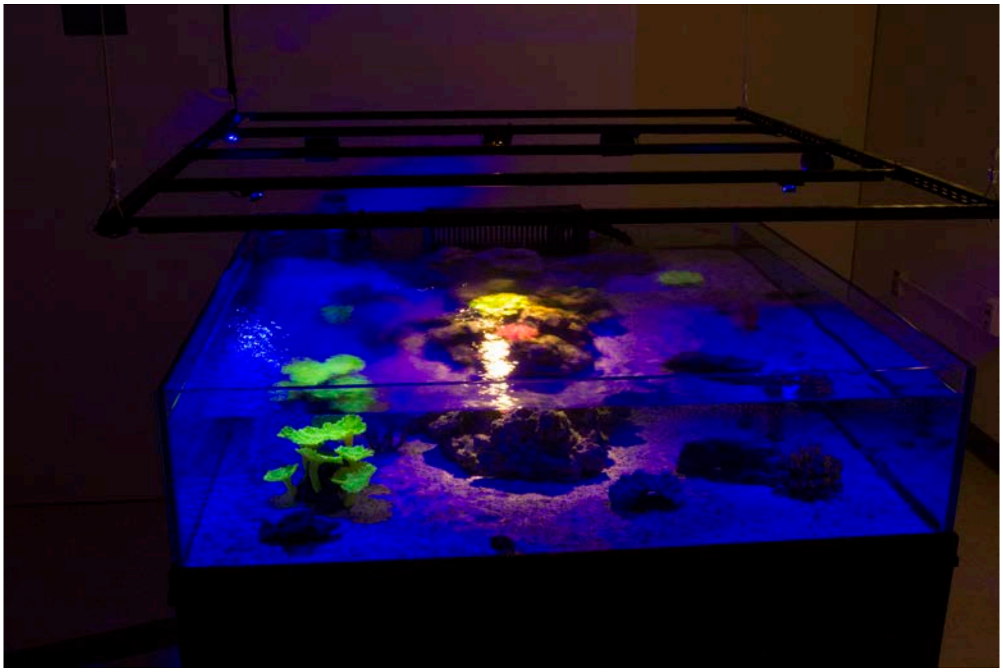
Reef photo D



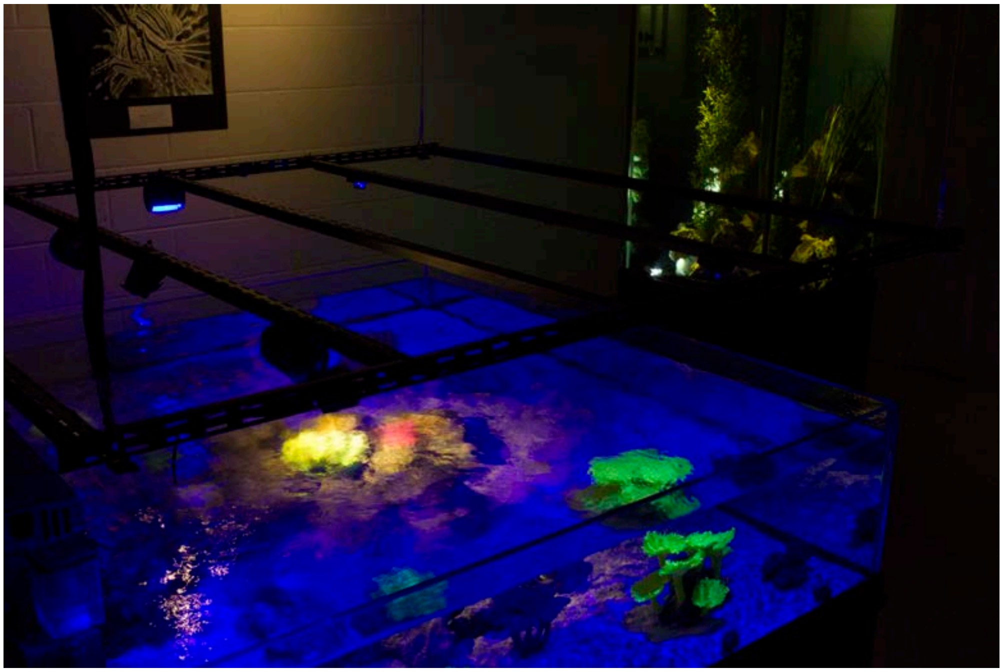
Reef photo E



Reef photo F



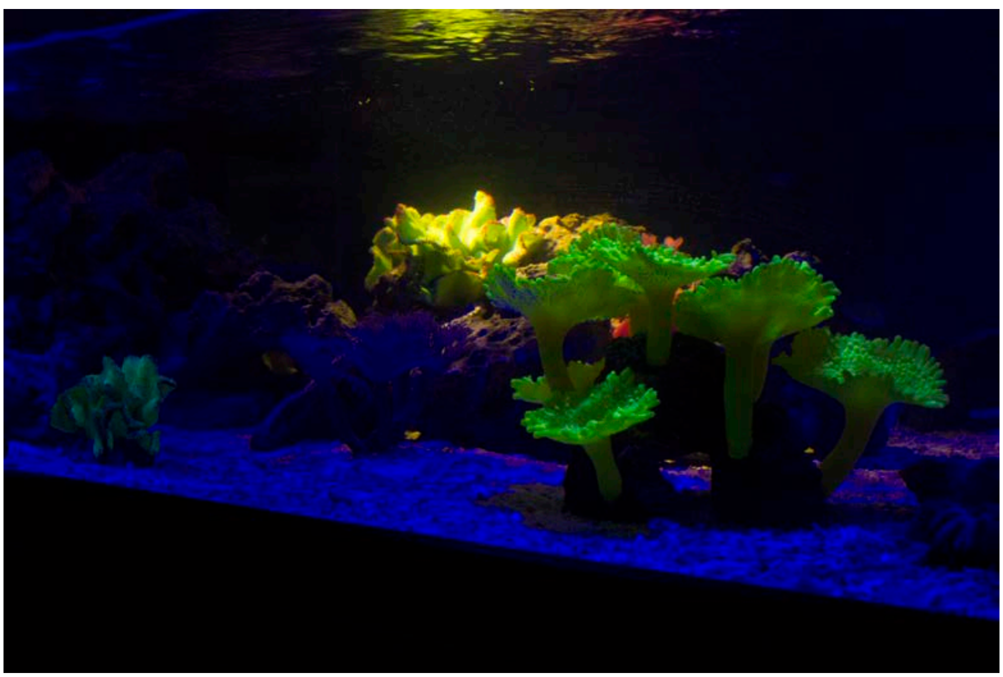
Reef photo G



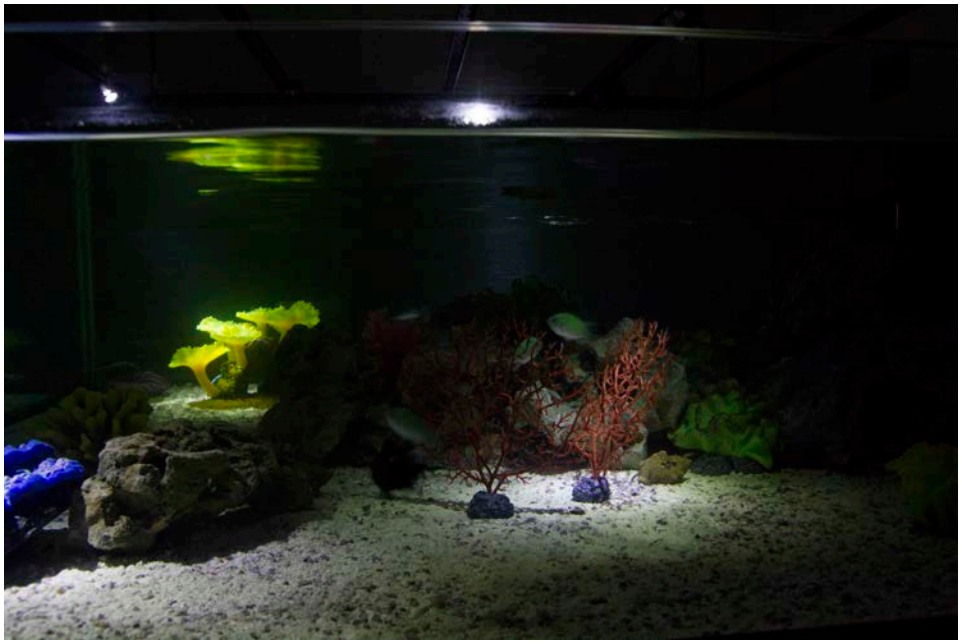
Reef photo H

Reef photo I

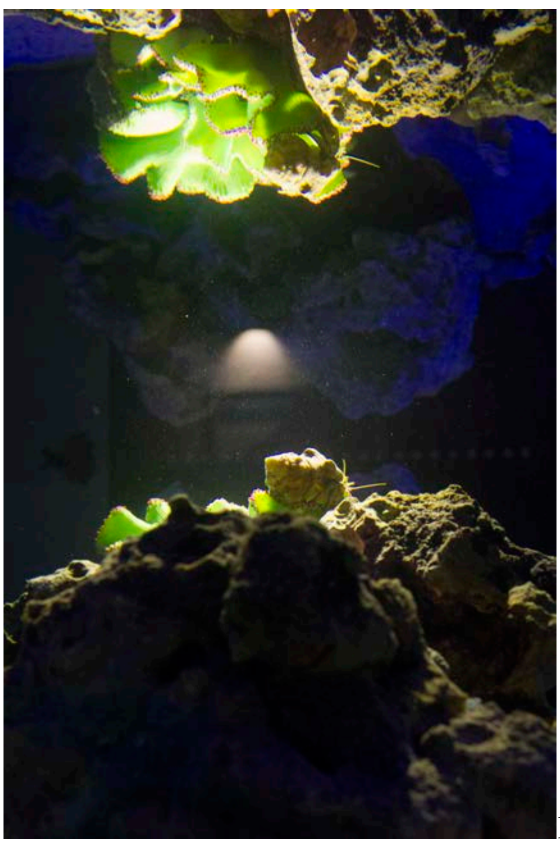
Reef photo J



Reef photo K



Reef photo L

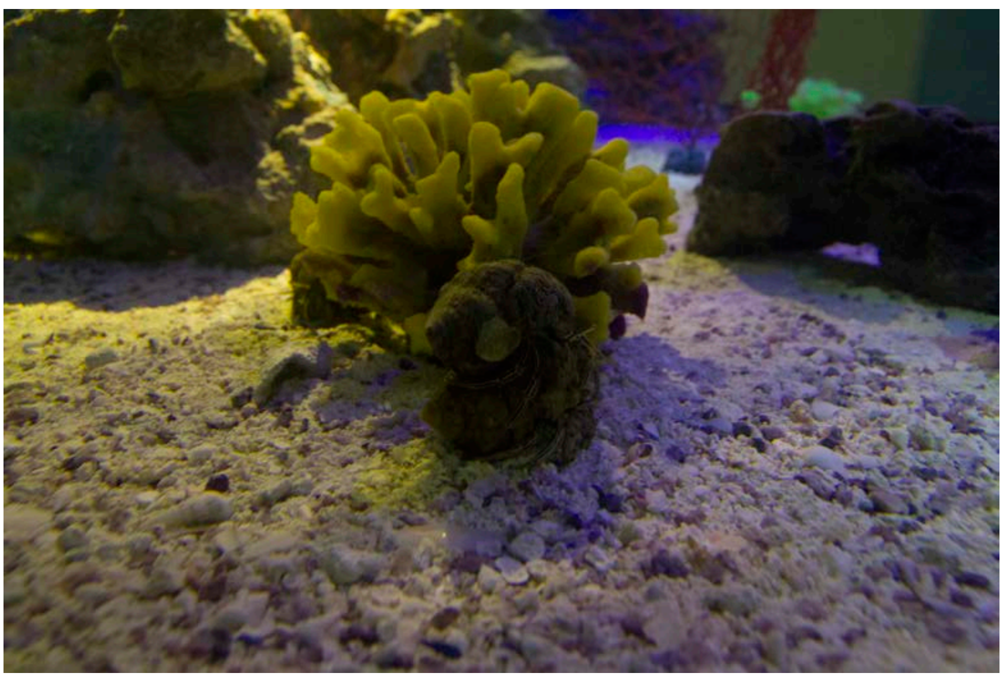


Reef photo M

Reef photo N

Reef photo O

Reef photo P



Reef photo Q

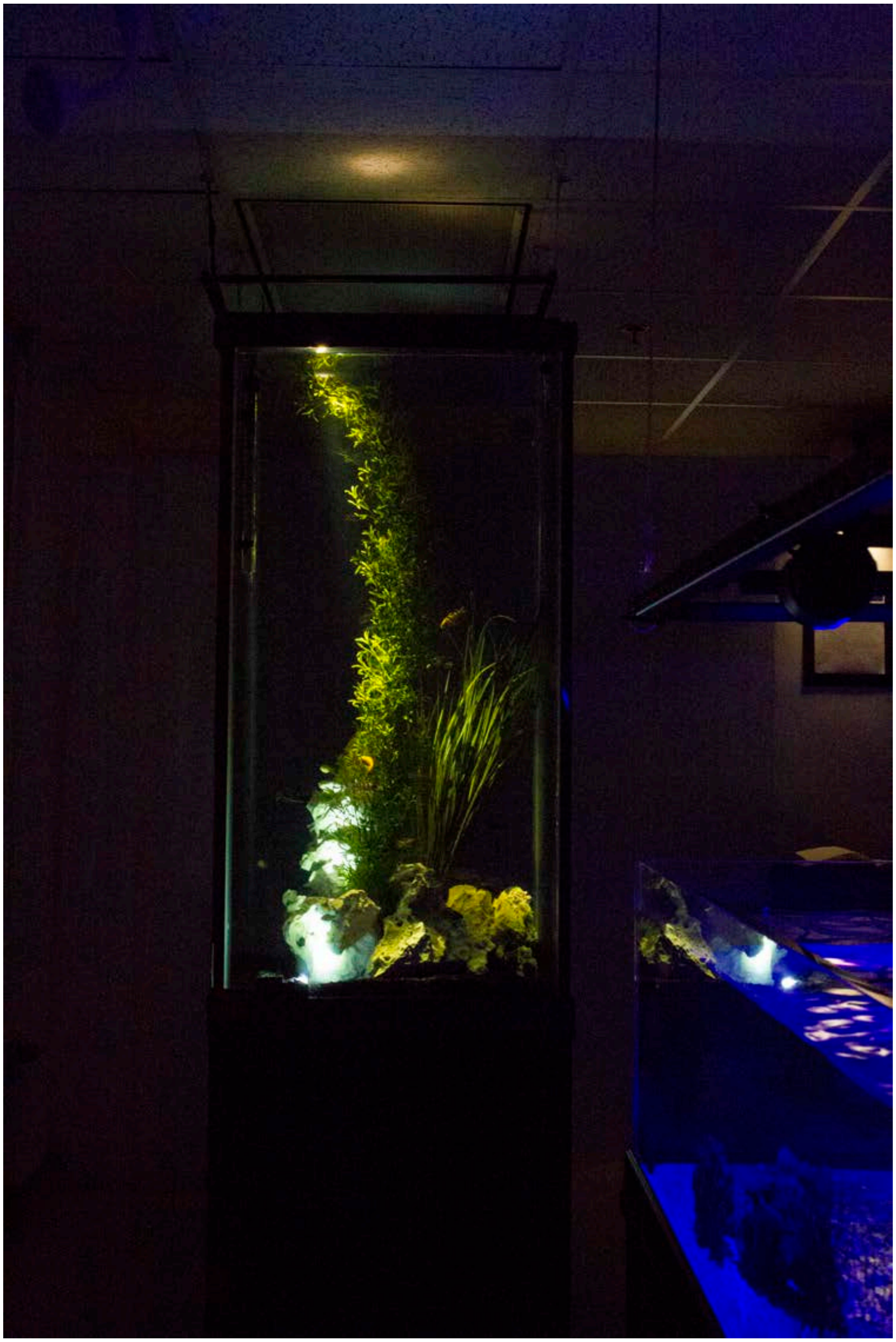
Reef photo R

APPENDIX E: PHOTOS OF FRESHWATER CICHLID MICROENVIRONMENT WITH PROTOTYPE DEMONSTRATION.

Cichlid photo A: Left side sunlight
Cichlid photo B: Left side sunlight far
Cichlid photo C: Front sunlight
Cichlid photo D: Right side transitional
Cichlid photo E: Front quarter twilight
Cichlid photo F: Front quarter sunstream
Cichlid photo G: Left side night. *
Cichlid photo H: Right side close up*
Cichlid photo I: Right side night*
Cichlid photo J: Right side deep night*
Cichlid photo K: Close up water perspective night*
Cichlid photo L: Right side depth perspective night*

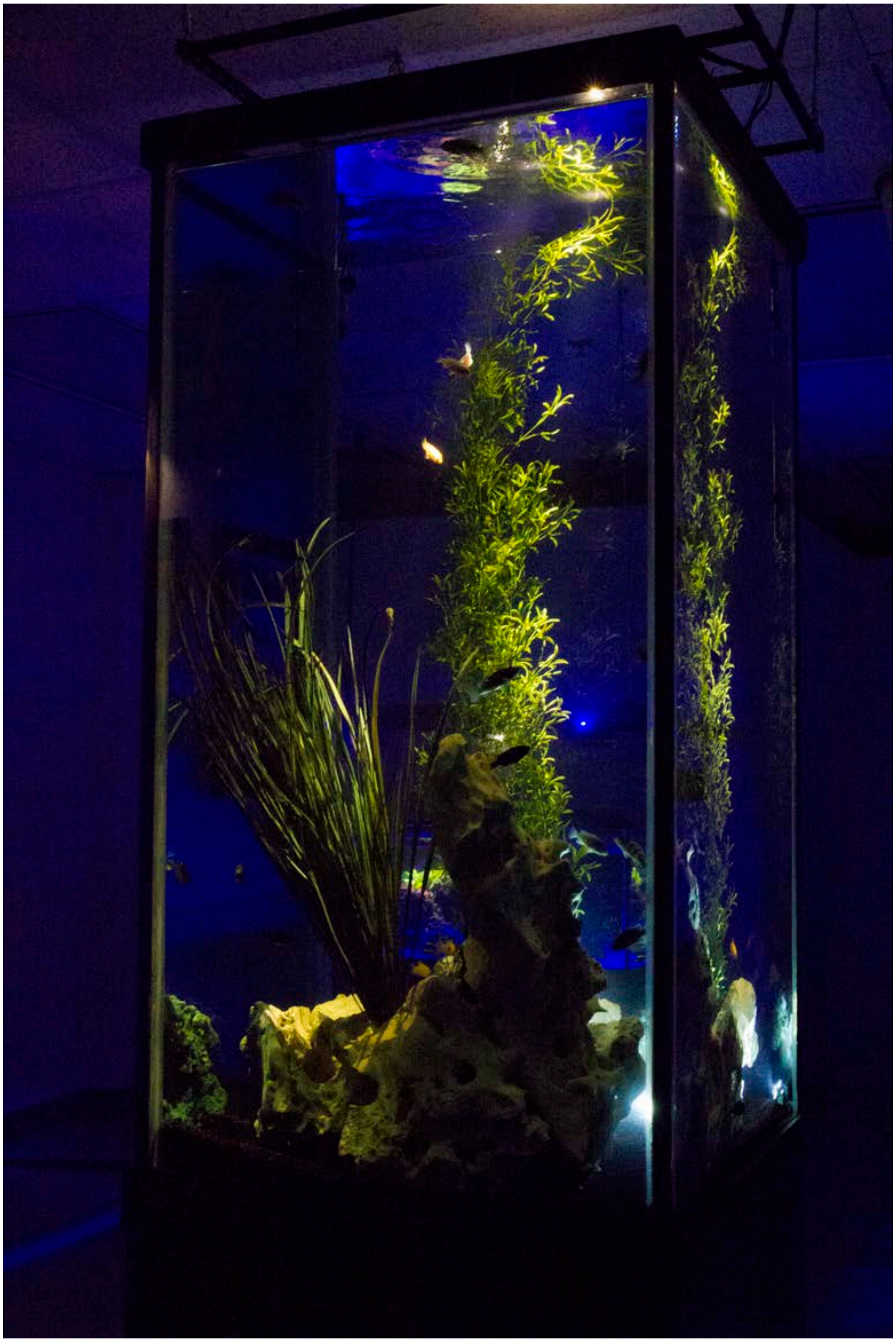
*Purple hue is result of warm-toned blue LED reflection on purple rock surface. No purple LEDs were used. The camera was more sensitive to this than the human eye was.

Cichlid photo A

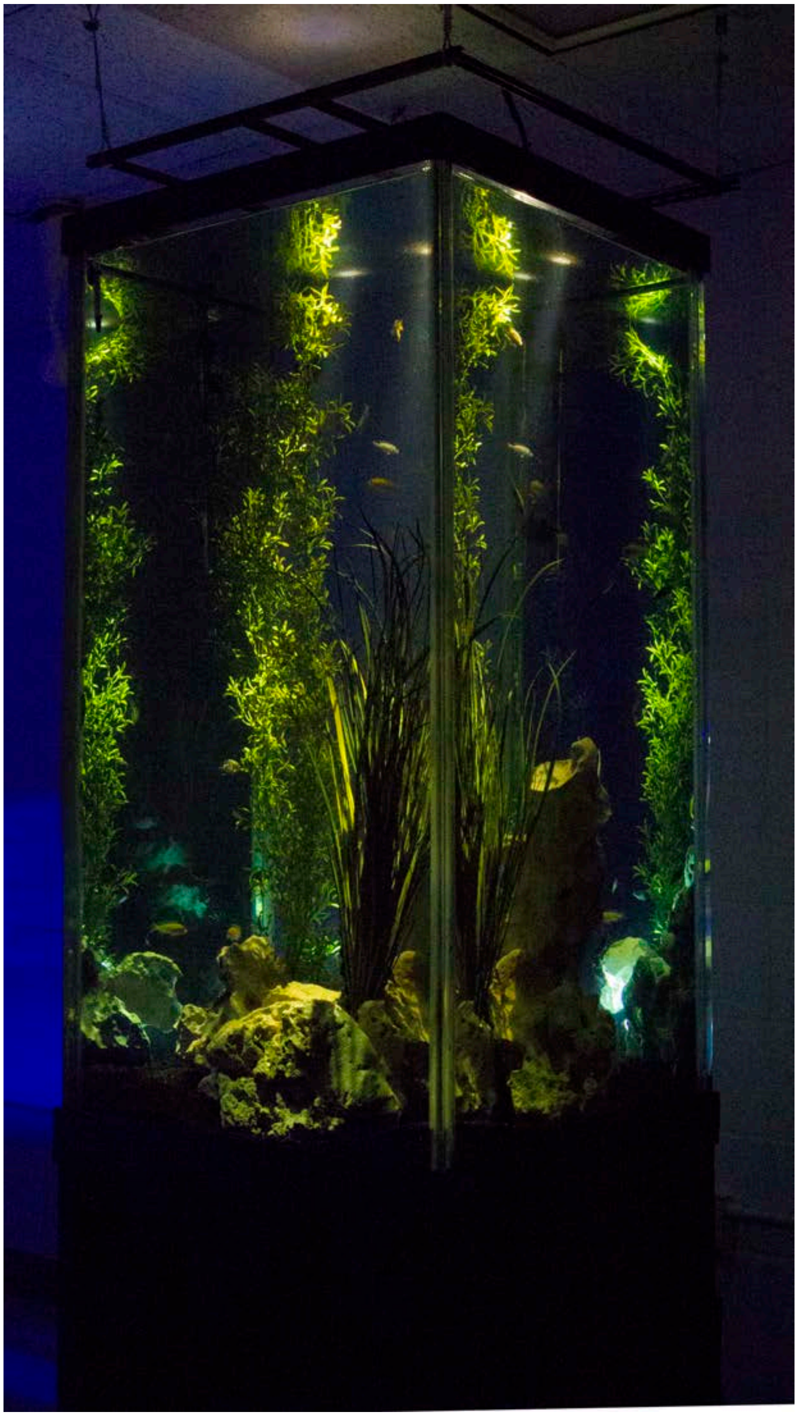


Cichlid photo B

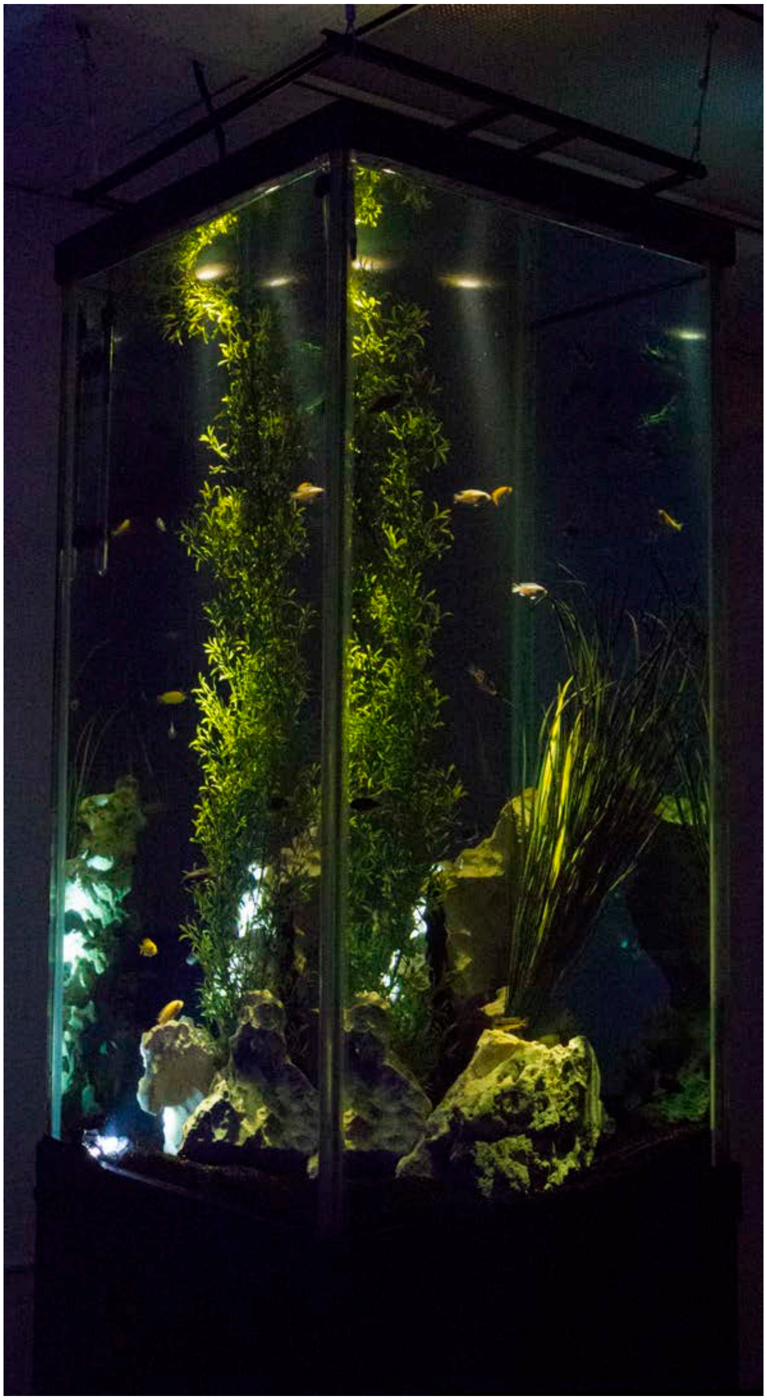
Cichlid photo C



Cichlid photo D



Cichlid photo E



Cichlid photo F

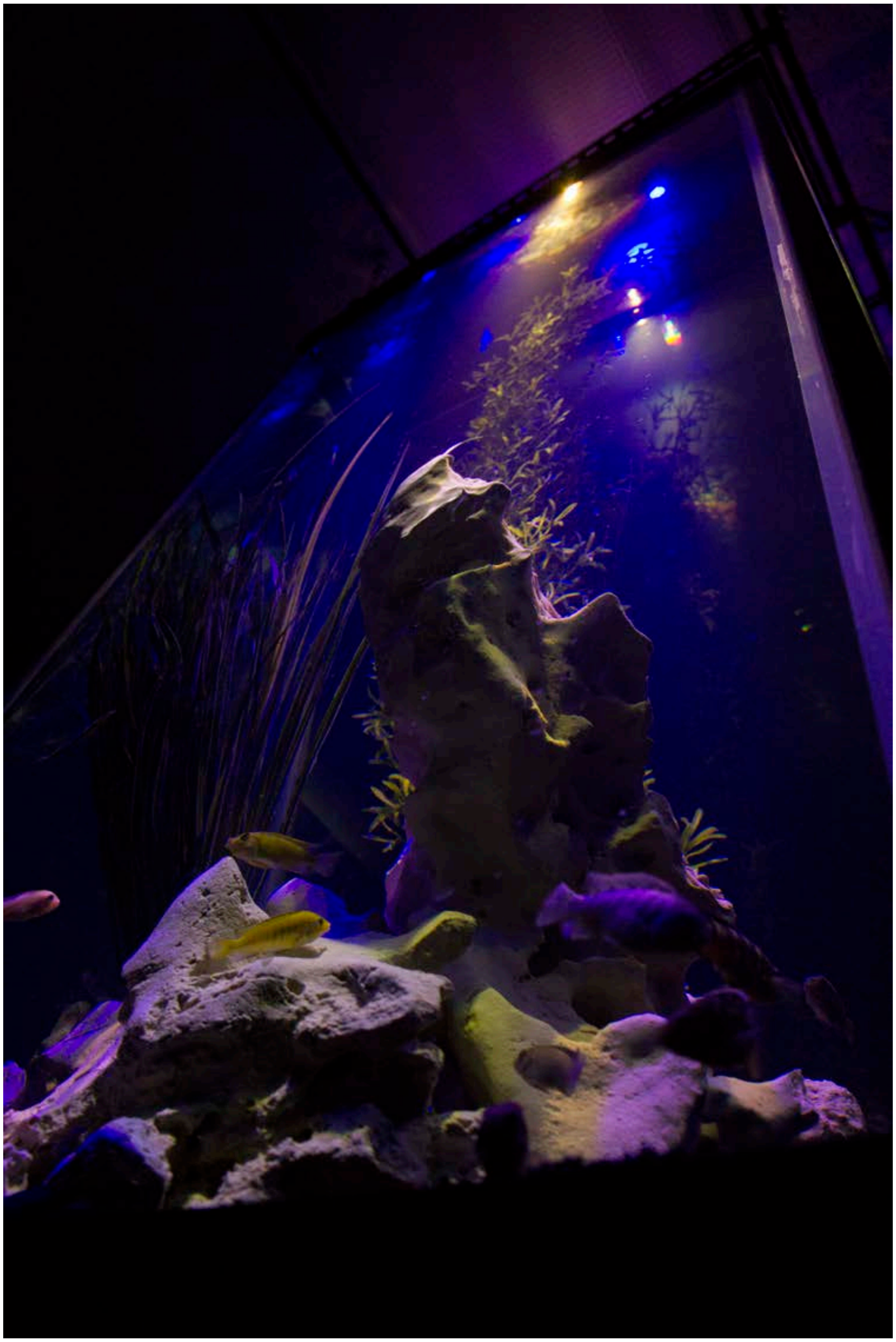
Cichlid photo G

Cichlid photo H


Cichlid photo I

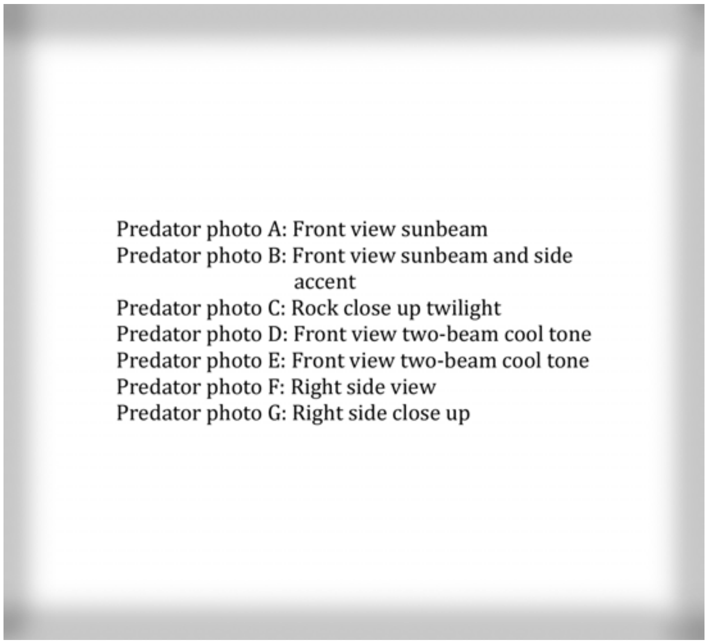
Cichlid photo J


Cichlid photo K



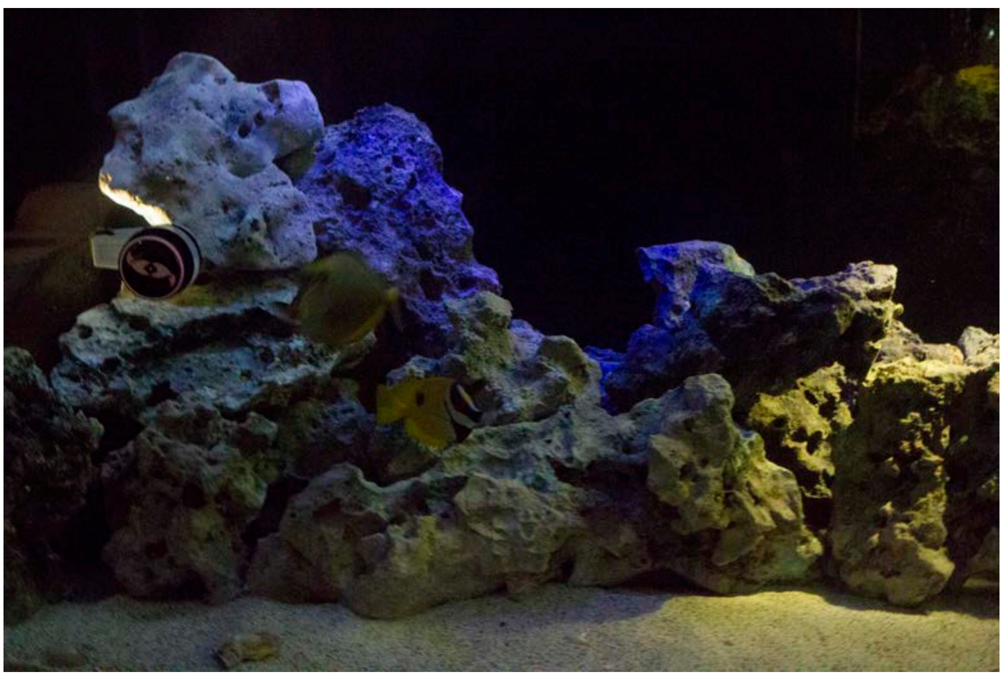
Cichlid photo L

APPENDIX F: PHOTOS OF SALTWATER PREDATOR MICROENVIRONMENT WITH PROTOTYPE DEMONSTRATION.



Predator photo A

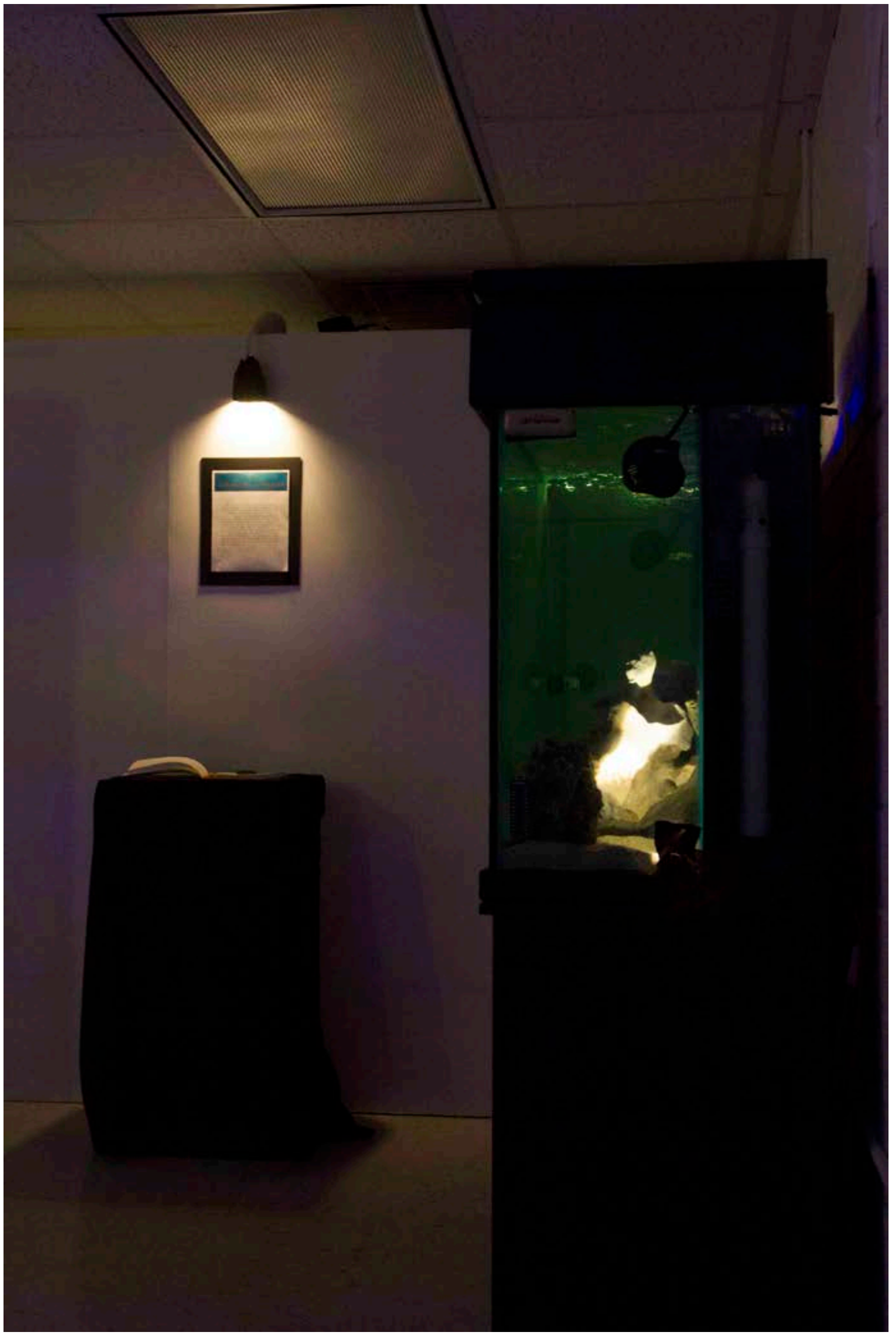
Predator photo B



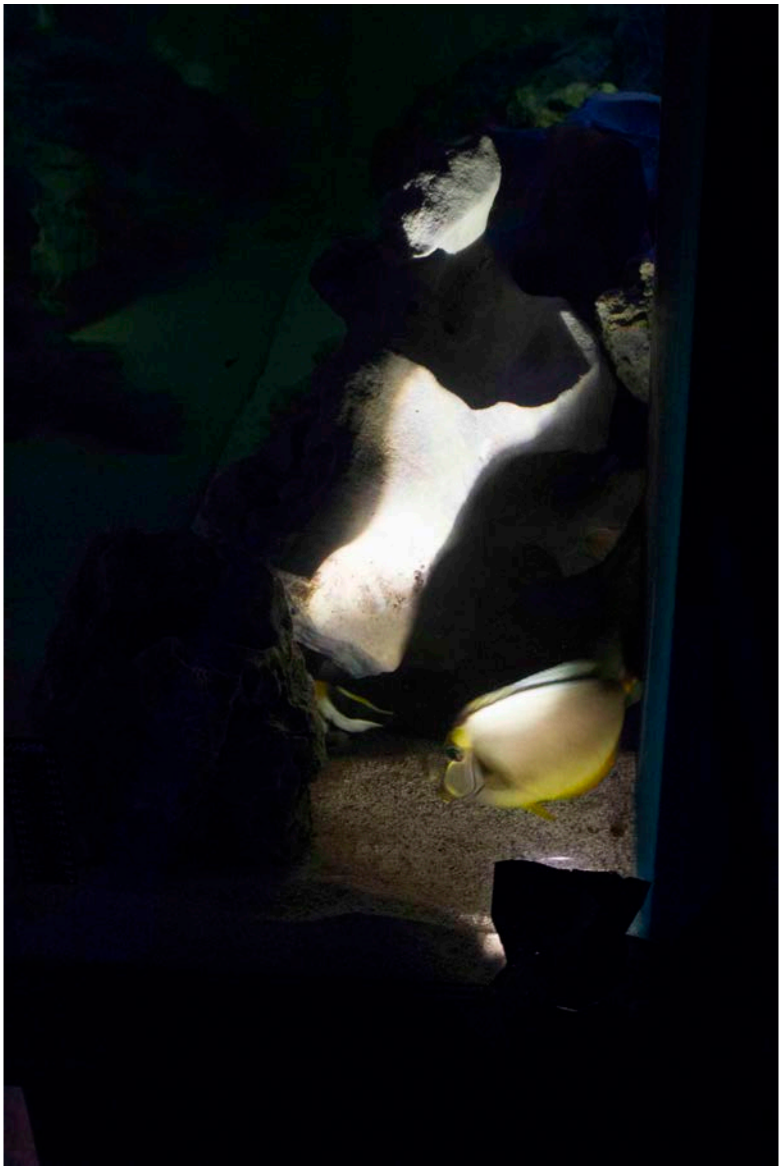
Predator photo C

Predator photo D

Predator photo E



Predator photo F



Predator photo G

Glossary

African Cichlids: Freshwater fish originating from Africa's great lakes; typically Lake Victoria, Lake Malawi and Lake Tanganyika.

Batten: A long thin piece of wood or metal that is used to connect and support other pieces of wood or metal.

Bottom Dwellers: Fish species that swim low near the substrate; commonly scavengers.

Color Temperature: Temperature at which a black body would emit radiation of the same color as a given object. For the use of this writing, it is the hue of light perceived.

Crepuscular: An animal or species that is active at twilight (sunrise and sunset) and are non-active (sleeping) during both the day and night hours.

Diurnal: An animal or species that is active during daylight hours and non-active (sleeping) during night hours.

Driver: An electrical device that regulates the power to an LED or string(s) of LEDs

Focusability: A sum of placement, pan, tilt, and lens degree.

Ground Plan: A drawing from the perspective of being above the topic that is being drawn. Used in the theatre to illustrate placement of objects such as set pieces and lighting instruments.

IACUC: Institutional Animal Care and Use Committee

LED: A light-emitting diode.

Light Spectrum: Wavelengths and frequencies that characterize light.

Microenvironment: A small usually distinctly specialized and effectively isolated habitat (as a forest canopy).

Mid-level swimmers: Fish species that are comfortable swimming at a mid-range, rather than the top level of the water, or the bottom level of the water.

Nocturnal: An animal or species that is active at night, and non-active (sleeping) during the day hours.

Pan: Side to side (horizontal) movement and orientation.

Photoperiod: Set times of darkness and light, as in night and day.

Potentiometer: A three-terminal resistor with a moving contact that forms an adjustable voltage divider.

Prototype: An early or preliminary model of something, from which other forms are further developed.

Protocol: A system of rules that explain the correct conduct and procedures to be followed in formal situations.

Resistor: Used to limit the current to a LED to a safe value.

Section: A drawing from a horizon line.

Shoaling: When a species of fish swim together for either safety or social reasons.

Tilt: Up and down (vertical) movement and orientation.

Top-level swimmers: Fish species that prefer to be close to the surface of the water.

Bibliography

Cato, James C. and Christopher L. Brown. Marine Ornamental Species. Ames, Ia: Iowa State Press. 2003

Delbeek, J. Charles and Julian Sprung, The Reef Aquarium Science, Art and Technology. Volume Three. Coconut Grove, Fl: Two Little Fishies, d.b.a. Ricordea Publishing. 2005.

Goldstein, Robert J Dr. Marine Reef Aquarium Handbook. Hauppauge, NY: Barron's Edu Series, 1997.

Kappel-Smith, Diana Night Life: Nature from Dusk to Dawn. Arizona: University of Arizonia Press, 1996.

Livengood, E.J and F.A Chapman. "The Ornamental Fish Trade: An Introduction with Perspectives for Responsible Aquarium Fish Ownership." Department of Fisheries and Aquatic Sciences UF/IFAS Extension. 2013. University of Florida IFAS Extension.

Nieuwenhuizen, A. van den. The Aquarium Beautiful. Philadelphia: Chelsea House. 1997

Riddle, Dana. "Aquarium Lighting: Moonlight-A Concise Review of Its Spectrum, Intensity, Photoperiod, and Relationship to Coral and Fish Spawning." Advanced Aquarist Feature Article. July 2012. Advanced Aquarist. Sep 2013

Riddle, Dana. "Effects of Yellow Water on Light Transmission in an Aquarium." Advanced Aquarist Feature Article. Jan 2014. Advanced Aquarist. Jan 2014

Scott, Michael. Marine Fishes. Neptune City: T.F.H Publications. 2001.

Strohmeyer, Carl. "Aquarium Lighting." American Aquarium Products. April 2014. American Aquarium Productions Aquatic Information. 2013

"Species Profiles." Microcosm Aquarium Explorer. Reef to Rainforest: Discovering Tropical Species Places and Nature. 2014 MICROCOSM, Ltd. Oct 2013.

"Species Search." Red List. The IUCN Red List of Threatened Species. April 2014. International Union for Conservation of Nature and Natural Resources. Oct 2013.